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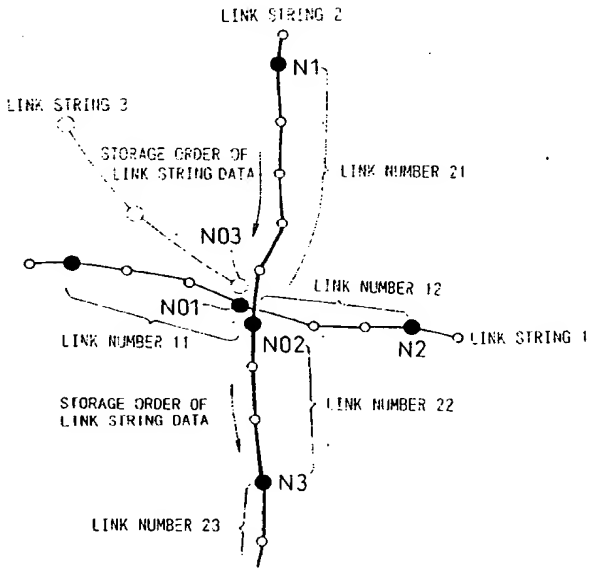
(54) Navigation system

(57) A navigation navigation system according to the present invention comprises: a database apparatus provided with map display data constituted of data representing road positions and physical forms provided in separate sets to correspond to different scales and route search data constituted of data representing connection states of one road connecting with another road provided in separate sets to correspond to different scales: and a control apparatus that, when displaying recommended route data obtained by performing a search using the route search data at a specific first scale superimposed upon a roadmap that is displayed on a monitor based upon map display data at a second scale that is larger than the first scale, reads out physical form data of the recommended route data obtained by performing the search using the route search data at the first scale based upon the map display data at the second scale and displays the physical form data superimposed upon the roadmap on the monitor.

FIG. 5



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a navigation system that is capable of searching a recommended route based upon a plurality of sets of map data at different scales and drawing the recommended route superimposed upon display maps at different scale.

2. Description of the Related Art

Vehicular navigation systems in the known art are provided with a function for displaying a roadmap of the area where the vehicle is currently located, a function for accurately detecting the vehicle position through map matching, a function for calculating a recommended route from a point of departure to a destination and the like. In these vehicular navigation systems in the prior art, roadmap display data, data for map matching and data for route search are separately stored in a CD ROM in order to maintain compatibility with existing software programs and also to improve the processing speed.

The roadmap display data include widest range map data for displaying large areas at the smallest scale, most detailed map data for displaying small areas in detail at the largest scale and a plurality of sets of map data at different scales between that of the widest range map data and that of the most detailed map data. For instance, the widest range map data may be referred to as level 4 data, the most detailed map data may be referred to as level 1 data and the sets of data at scales between those of the level 4 data and the level 1 data may be referred to as level 3 data and level 2 data. In that case, the route search data include two sets of data that correspond to the level 4 and level 2 roadmap data, and the vicinity of the point of departure and the vicinity of the destination are searched using the level 2 data and the other area is searched using the level 4 data for route search to reduce the length of time required for the route search.

In this specification, a level with a large level number is referred to as a high order level, whereas a level with a small level number is referred to as a low order level.

FIG. 21 illustrates a roadmap depiction of roadmap display data which are stored in memory as level 4 data and level 3 data. The level 4 roadmap display data and the level 3 roadmap display data are separately stored in CD ROM media. FIG. 21A shows a roadmap corresponding to one of the meshes in the level 4 data, i.e., a mesh M4, in which a road D1 and two roads D2 and D3 that connect at intersections C1 and C2 at the two ends of the road D1 are present. One of the small areas achieved by dividing one of the meshes of the level 4 data, i.e., the mesh M4 equally into sixteen portions, i.e., the hatched small area m3, constitutes a mesh of the level 3 data, i.e., a mesh M3 and, as shown in FIG. 21B, only a portion of the road D1, i.e., a road D4 is present in the mesh M3.

There is a problem in the system in the prior art described above in that when the recommended route is displayed superimposed upon a roadmap at level 2 or level 1 displayed on the monitor based upon the recommended route data which constitute the results of a route search performed at level 4, a great length of time is required for data conversion processing.

Also, if the detail button is operated while the roadmap corresponding to the mesh M4 in the level 4 data is displayed on the monitor, the roadmap corresponding to the mesh M3 in the level 3 data will be displayed on the monitor. However, since there are no identification data to indicate that the road D1 and the road D4 are the same road, it is difficult to make a given road correspond through the different levels. In addition, a similar problem exists in regard to the route search data, and it is difficult to make the data searched at level 2 correspond to the data searched at level 4 in recommended route data that are the result of a route search. Moreover, since there are no identification data to indicate that a road in the roadmap display data and a road in the route search data are the same, it is difficult to achieve correspondence of a given road when the recommended route data are superimposed upon the roadmap display data.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a navigation system with which the processing time for superimposing a recommended route upon a display map at a lower order level by using recommended route data at a higher order level is reduced.

In order to attain this object, a navigation system according to the present invention comprises: a database apparatus provided with map display data constituted of data representing road positions and physical forms provided in separate sets to correspond to different scales and route search data constituted of data representing connection states of one road connecting with another road provided in separate sets to correspond to different scales; and a control apparatus that, when displaying recommended route data obtained by performing a search using the route search data at a specific first scale superimposed upon a roadmap that is displayed on a monitor based upon map display data at a second scale that is larger than the first scale, reads out physical form data of the recommended route data obtained by performing the search using the route search data at the first scale based upon the map display data at the second scale and displays the physical form data superimposed upon the roadmap on the monitor.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a block diagram of an embodiment of a navigation system for vehicles according to the present invention.

FIG. 2 shows an example of two roads intersecting within a mesh range.

FIG. 3 shows a diagram illustrating link string data.

FIG. 4 shows the structure of roadmap display data.

FIG. 5 shows an example of a roadmap with a plurality of nodes and a plurality of interpolation points.

FIG. 6 shows a diagram illustrating the link string data corresponding to the road indicated with the bold line in FIG. 5.

FIG. 7 shows a diagram illustrating offset information that is added into link string data for reading out immediately preceding data.

FIG. 8 shows a method for reading out the link string data from the rear end.

FIGs. 9A through 9D show different data lengths of node information and interpolation point information.

FIGs. 10A and 10B show an example of attribute 1 + X coordinate data.

FIGs. 11A and IIB show an example of attribute 2 + Y coordinate data.

FIG. 12 shows a diagram illustrating link numbers in route search data.

FIG. 13 shows the structure of route search data.

FIG. 14 shows an overview of the structure in the recommended route data.

FIGs. 15A and 15B show a detailed diagram illustrating the data structure of the node information and the link information in the recommended route data.

FIG. 16 shows a flowchart outlining the main processing performed by the control circuit.

FIG. 17 shows the flowchart continuing from FIG. 16.

FIG. 18 shows a detailed flowchart illustrating the background map drawing processing performed in step S8 in FIG. 17.

FIG. 19 shows a detailed flowchart illustrating the recommended route drawing processing performed in step S9 in FIG. 17.

FIGs. 20A through 20C show the procedure taken for drawing a recommended route in the image memory based upon the recommended route data in this embodiment.

FIGs. 21A and 21B show a diagram illustrating link strings and links at different levels.

FIG. 22 shows an example of link data and node data in the prior art.

FIG. 23 shows a diagram illustrating an example of the prior art in which the separate segments of a road are assigned to separate links across an intersection.

FIG. 24 shows the relationship between route search data and route display data in the prior art.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 is a block diagram of an embodiment of a navigation system for vehicles that is internally provided with a map database apparatus according to the present invention. In FIG. 1, reference number 1 indicates a current position detection apparatus that detects the current position of a vehicle, which is constituted with, for instance, an azimuth sensor that detects the bearing of the vehicle while traveling, a vehicle speed sensor that detects the speed of the vehicle, a GPS sensor that detects a GPS signal from a GPS (Global Positioning System) satellite and the like.

Reference number 2 indicates a control circuit that controls the entire system and is constituted with a microprocessor and peripheral circuits. Reference number 3 indicates an input device for inputting destinations and the like for vehicles, reference number 4 indicates a DRAM that stores vehicle position information and the like detected by the current position detection apparatus 1, reference number 5 is an image memory that stores image data for display on a display device 6 and image data stored in the image memory 5 are read.out as necessary to be displayed on the display device 6. Reference number 7 indicates an SRAM that stores node information, link information and the like on the recommended route calculated by the control circuit 2.

Reference number 8 indicates a map database apparatus that stores various types of data for performing roadmap display, route search, map matching and the like, which is constituted with, for instance, a CD ROM device, a magnetic recording device and the like. In the map database apparatus 8, map display data that constitute information related to road physical forms, road classifications and the like, and route search data that constitute branching point information, intersection information and the like that are not directly related to road physical forms, are stored. The map display data are mainly used when displaying a roadmap on the display device 6 and the route search data are mainly used when calculating a recommended route.

Next, the data structures of the map display data and the route search data stored in the map database apparatus 8 are described.

[1] Map display data

(1) Overview of link string data

Data management of the map display data in this embodiment is performed for each mesh range representing one of the partitioned areas achieved by dividing a roadmap into specific ranges, and individual roads present in a mesh range constitute separate link strings. For instance, as shown in FIG. 2, when two roads D1 and D2 intersect in one mesh range, the two roads constitute separate link strings 1 and 2, with the link string

1 comprising links 11 and 12 and the link string 2 comprising links 21 - 23. In this example, the links in the link string 1 and the links in the link string 2 represent roads of the same type. A link is the minimum unit that can represent a road and, in FIG. 2, the segment between the intersections constitutes one link unit, with inherent numbers assigned to the individual links (hereafter referred to as link numbers) for identification. The intersections in FIG. 2, i.e., the connection points of the individual links are expressed as nodes N0 N4. Nodes also constitute the start points and the end points of the individual links and, as detailed later, interpolation points that further divide the segments between nodes may sometimes be provided as well.

Also, in this embodiment, when there is a distinct structure such as a bridge, a tunnel or the like, on a road, the portions of the road preceding and following the structure constitute separate link strings. For instance, when there is a bridge and a tunnel on National Highway 246, as shown in FIG. 3, the portions preceding the bridge and the tunnel, the blocks corresponding to the bridge and the tunnel and the portions following the bridge and the tunnel all constitute separate link strings. In FIG. 3, these strings are designated as link strings 101 - 105. By making the portions preceding and following a distinctive structure on a road separate link strings, search of bridges, tunnels and the like on a roadmap is facilitated.

The map display data comprise a plurality of sets of data at different scales. In the explanation of this embodiment, the data at each scale are referred to as level n (n may be 1 4, for instance) data. Level 1 corresponds to the most detailed roadmap and as the level goes up, a roadmap over a wider range is presented at a smaller scale. Furthermore, as detailed later, in this embodiment, identical links at different levels are managed with identical (inherent) link number to facilitate making data correspond among different levels. The link number will be explained later.

(2) Data structure of link string data

To give an explanation of the roads in FIG. 2, the map display data are structured by providing sets of link string data, each including various types of information related to the link string 1 or 2-n, for individual link strings, as shown in FIG. 4, and the data corresponding to each link string include link string information and node link information, with the link string information comprising the following types of data, as shown in FIG. 4.

1 link string size
2 number of element points
3 link attribute
4 road name offset
5 road number

In addition, the node link information comprises the following types of data, as shown in FIG. 4.

1 attribute 1 + X coordinate
2 attribute 2 + Y coordinate
3 identical node offset
4 guide offset
5 link number
6 altitude information

(3) Link string information

In FIG. 4, the link string size represents the storage size of the link string data, by referring to this storage size, prompt access to the next link string data is achieved. The number of element points data indicate the total number of node points and interpolation points, the link attribute data indicate the type of road, such as a national highway, a prefectural road, an expressway or the like and the road number is the actual designation number assigned to a national highway or prefectural road. The explanation of the road name offset is omitted since it is not relevant to this embodiment. The interpolation points are to be explained later.

(4) Node link information

FIG. 5 shows the link strings 1 and 2 in FIG. 2 in more detail. For instance, the node link information of the link string 2 indicated with the bold line in FIG. 5 is as shown in FIG. 6. As shown in the figure, the data on the link string 2 include node information related to nodes N1, N02 and N3 (filled circles in FIG. 5) on the link string and interpolation point information related to the interpolation points (outline circles in FIG. 5). The node information includes positional X and Y coordinates of the node, the attribute and the link numbers of links connected to the node, whereas the interpolation point information includes the positional X and Y coordinates of the interpolation point. These positional coordinates are used as physical form data for recommended route display or physical form data for map matching, to be detailed later. The link string 2 indicated with the bold line in FIG. 5 includes a link assigned with a link number 21 located between the nodes N1 and N02, a link assigned with a link number 22 located between the nodes N02 and N3 and a link assigned with a link number 23 connected to the node N3. As is obvious from FIG. 6, the node information on the node N02 is shared by the link with link number 21 and the link with link number 22. The node information and the interpolation point information are positioned in the data structure in the order in which the links are connected. Thus, by sequentially reading out the link string data starting with the front end address, the road physical form, the road type and the like of the overall link string can be detected.

As has been explained, since, in this embodiment,

data are managed in units of link strings within one mesh range and nodes between adjacent links are shared by the adjacent links, the entire volume of the data can be reduced compared to the case in which the data are managed in units of links, as in the example of the prior art shown in FIG. 22. In FIG. 22, links L0 - L3 have nodes N0b, N1a, N1b ... N3a at their start points and end points and sets of identical node information C01, C10 ... for indicating identical nodes are provided as connection information for the individual nodes.

(5) Offset indicating an identical node

In FIG. 5, of the nodes at the intersection of the link string 1 and the link string 2 and the link string 3, the node in the link string 1 is assigned with a reference number N01, the node in the link string 2 is assigned with a reference number N02 and the node in the link string 3 is assigned with a reference number N03. In the data structure, the sets of node information corresponding to the intersecting points N01 N03 each has a data item referred to as an identical node offset.

The identical node offset is explained in detail in reference to FIG. 7. For instance, the address value indicating a storage area for the node information of the node N01 in the link string 1 is stored in memory as the identical node offset of the node N02 in the link string 2. Likewise, the address value indicating the storage area for the node information of the link string 3 is stored in memory as the identical node offset of the node N01 of the link string 1 and the address value of the address at which the node information of the node N02 in the link string 2 is stored in memory as the identical node offset of the node N03 in the link string 3.

Since nodes other than those at intersection, which are indicated as the intersecting points N01 - N03 in FIG. 5, do not intersect other roads, a specific value, i.e., FFFFh, for instance, that indicates that no other node exists to constitute an identical node, is stored in the identical node offset storage areas of the node information for these nodes.

By providing the identical node offset in this manner, even when there are a plurality of sets of node information in regard to identical nodes, as in the case of an intersection, the corresponding relationships among the individual sets of node information can be easily ascertained. Also, in contrast to an apparatus in the prior art shown in FIG. 23, which requires 5 nodes (N0a - N0d) corresponding to the intersection where three roads intersect, only three nodes (N01-N03) are required in this embodiment, as shown in FIG. 5, achieving a reduction in the data volume.

(6) Attribute 1

The attribute 1, which is stored together with the X coordinate of a node is constituted of offset information for reading out the link string data in the reverse direction. As explained earlier, in the link string data, the node information and the interpolation point information and the like are positioned in the order in which the actual connections are made. Because of this, by reading out the link string data sequentially from the front end address in the storage area, the road physical form can be accurately ascertained starting at the front end position.

There are also situations in which it is necessary to ascertain the road physical forms from the end by reading out the link string data from the end. In such a case, after reading out the node information or the interpolation point information at the rear end, the header position of the node information or the like that is set immediately before in data arrangement must be detected. For instance, when reading out the link string data (FIG. 6) of the link indicated with the bold line in FIG. 5 from the end, it is necessary to first read out the node information on the node N3 and then to detect the header position of the interpolation point information that is set immediately before in the data arrangement to read out the interpolation point information from this header position, as indicated with the arrows in FIG. 8. However, as explained below, the data volume of the node information and the interpolation point information varies among various nodes and interpolation points, and the header positions of node information and interpolation point information cannot be determined uniformly.

FIGS. 9A - 9D shows varying data volumes of node information and interpolation point information, with FIG. 9A representing a case in which node information or the like is constituted with two words, i.e., the X and Y positional coordinates, FIG. 9B representing a case in which node information or the like is constituted with three words by adding identical node offset to the two words in FIG. 9A, FIG. 9C representing a case in which node information or the like is constituted of four words by adding guide offset information to the three words in FIG. 9B and FIG. 9D representing a case in which node information or the like is constituted of five words by adding a link no. to the four words in FIG. 9C.

As shown in FIGS. 9A - 9D, since the data volume of node information or interpolation point information varies for each case, the information that indicates the header positions of the node information and the interpolation point information is added to the link string data in advance as attribute 1 data in this embodiment. In this embodiment, they are added together with the X positional coordinates of the individual nodes and interpolation points.

For instance, FIG. 10A shows an example in which the X positional coordinates are stored in the lower order 11 bits and information that indicates the header positions of various sets of node information and the like is stored in the higher order 2 bits, in the 2-byte data constituting the attribute 1 + X coordinate data. The information that indicates the number of words that are present up to the header position of each set of node

information or the like is stored in these higher order 2 bits.

Thus, since the information that indicates the header position of the immediately preceding set of node information or the like is added to the link string data in this embodiment, even when the link string data are read out in the reverse direction, the entire node information or the like can be read out without omissions.

(7) Attribute 2

The attribute 2, which is stored together with the Y coordinate of a node, includes traffic regulation information, road width information and number of lanes information. The data length of each set of data of the node link information that constitutes the link string data is 16 bits (2 bytes = 1 word). In the lower order 11 bits of the data indicating the attribute 2 + Y coordinate, the Y positional coordinates are stored and in the higher order 5 bits, the traffic regulation information, the road width information and the number of lanes information are stored, as shown in FIG. 11A. One type of the information from 1 - 8 in FIG. 11B is selected through a specific bit combination for the higher order 5 bits.

Since the road width information, the traffic regulation information and the number of lanes information are stored by using the available bits in the 2 byte data for storing the positional coordinates or the like of a node, the road width information, the traffic regulation information and the like can be added to the link string data without having to increase the volume of data.

(8) Altitude information

When displaying a roadmap in three dimensions, data concerning the altitude differences among a plurality of points on the roadmap are required. Accordingly, as shown in FIG. 4 in this embodiment, all the altitude information on the various links constituting a link string is added at the end of the link string data. It is to be noted that since link string data including altitude information and link string data without altitude information are present together, each set of altitude information can be added to a plurality of nodes and a plurality of interpolation points.

By adding the altitude information to the link string data, a roadmap can be displayed in three dimensions. In addition, since all the altitude information is added together at the end of the link string data , the altitude information can be read out only when it is required and when the altitude information is not required, such as when displaying a regular flat map, for instance, only the data immediately preceding the altitude information need be read out.

(9) Inherent link numbers shared among levels

A link number is stored between sets of the attribute 1 + X coordinate and the attribute 2 + Y coordinate of node for each link. In this embodiment, the link number assigned to a link at the highest order level is also assigned as the link number of corresponding links at lower order levels. In other words, the link number assigned to a link at the highest order level is also assigned as the link number of the corresponding links at the lower order levels as the inherent link number.

Link numbers are explained in further detail in reference to an example shown in FIG. 12. It is to be noted that, in order to facilitate understanding, the explanation will be given on the data at levels 6, 4, 2 and 0 among the seven levels, i.e., levels 6 0. When the link string 1 at the highest order level 6 comprises one link assigned with link number 1, the link with the link number 1 at the highest order level 6 comprises two links sharing the identical link number 1 at level 4. The identical link at the highest order level 6 is constituted of the two links assigned with the link number 1 constituting the link string 1 and a link with the link number 1 which constitutes the link string 2 at level 2, whereas the link string is constituted of a link with the link number 1 constituting the link string 1, a link with the link number 1 constituting the link string 2 and two links with the link number 1 constituting the link string 3 at level 0.

By using a link number identical to that used at a higher order level for the link number of links at lower order levels that correspond to links at the higher order levels in this manner, the correspondence among identical link strings at different levels and the correspondence of identical link strings in the map display data and the route search data are facilitated, thereby achieving a reduction in processing time. [2] Route search data

The route search data include a plurality of sets of data corresponding to a plurality of sets of roadmap display data for different scales, and the data for each scale are referred to as level m (m, may be, for instance, 2, 4) data. In addition, as explained before in this embodiment, identical links at different levels are managed through identical link number to facilitate correspondence of data at different levels and the correspondence with the roadmap display data.

FIG. 13 shows the data structure of route search data. As shown in the figure, in the route search data, node information that indicates the connecting relationship with other nodes is stored for each connecting point (node) of links, which are the minimum units for expressing a road physical form. Each set of node information is constituted with home node information and adjacent node information, with the node positional coordinates stored in the home node information. In the adjacent node information, as shown in the figure, the adjacent node no., the link no. from the home node to the adjacent node, the link cost of the link and traffic regulation information on that link are stored. Also, various sets of node information are stored in the order of link connections and the node no. of the home node can be ascertained by the order in which it is stored. Because of this, even

without storing the node nos. of the home nodes as home node information, the node nos. of the home nodes can be ascertained, achieving a reduction in memory requirement.

[3] Recommended route data

FIG. 14 shows an outline of the data structure of recommended route data which represent a recommended route from a point of departure to a destination which has been searched based upon the route search data. In the recommended route data, node information and link information on the recommended route are stored, while classified in units of mesh ranges. It is to be noted that a mesh range refers to a partitioned range when a roadmap is partitioned into units of specific ranges.

As shown in FIG. 14, the recommended route data are constituted with a mesh code, the number of nodes, node information, the number of link classifications, link information, ferry information and tunnel information. The number for identifying the mesh range is stored in the storage area for the mesh code, the number of nodes present within a mesh range is stored in the storage area for the number of nodes and, as shown in detail in FIG. 15A, the node no., the positional coordinates, the distance cost and the like of each node within a mesh range are stored in the storage area for the node information. In addition, the number of link classifications that are present inside a mesh range is stored in the storage area for the number of link classifications and, as shown in detail in FIG. 15B, the link classification, the number of links, the link no. and the like of each link within a mesh range are stored in the storage area for the link information. FIG.s 15A and 15B illustrate a case in which there are two link strings 1 and 2 within the area indicated by the same mesh code.

It is to be noted that, as explained above, recommended route data are prepared at different levels and, in this embodiment, recommended route data at level 2 are prepared for the vicinities of the start point and the end point on the recommended route while recommended route data at level 4 are prepared for the middle range between the start point and the end point.

The following is an explanation of the operation performed in this embodiment in reference to the flowchart, and in this embodiment, the recommended route is displayed on the display device 6 in the following manner. The recommended route is searched by using the route search data at level 4 and level 2 to create recommended route data at level 4 and level 2, and then, the recommended route data at level 4 is converted into recommended route data at level 2, and then based upon the recommended route data at level 2 and the roadmap display data at level 2 and level 1, the recommended route is drawn and superimposed upon the roadmap at level 2 or level 1, which is displayed on the display device 6, with the recommended route highlighted with a red bold line, for instance.

FIGS. 16 and 17 are a flow chart illustrating the outline of the main processing performed by the control circuit 2. In step S1 in FIG. 16, the vehicle position is detected by the current position detection apparatus 1. In step S2, the destination, which has been input via the input device 3, is read in. In step S3, based upon the map display data stored in the map database apparatus 8, the start point and the end point of the route search are set on roads for which route search is possible. For instance, the start point of a vehicle may be the current position of the vehicle (vehicle position) and the end point is the destination.

In step S4, using route search data at level 2, route search in the vicinity of the start point of the route search is performed, and a plurality of candidates for the recommended route in the vicinity of the start point are selected. In step S5, using route search data at level 2, route search in the vicinity of the end point of the route search is performed, and a plurality of candidates for the recommended route in the vicinity of the end point are selected.

In step S6, using route search data at level 4, route search is performed for routes between the candidates for the recommended routes selected in step S4 and step S5, and a recommended route from the start point to the end point is calculated.

Route search data at different levels are used for the vicinities of the start point and the end point, and the middle range between the start point and the end point in this manner because if route search is performed using route search data at level 2 for the entire route, the data quantity will be very large and, as a result, the calculation time required in route search will increase. In step S7, the information related to the recommended route calculated in step S6 is stored in the SRAM 7 as recommended route data.

When the processing performed in step S7 in FIG. 16 is completed, the operation proceeds to step S8 shown in FIG. 17, in which the background map drawing processing, the details of which are shown in FIG. 18, is performed to draw (store) data related to the roadmap in the vicinity of the recommended route in the image memory 5 for display on the display device 6. First, in step S11 in FIG. 18, map display data corresponding to the vicinity of the current vehicle position are read from the map database apparatus 8. Next, in step S12, a portion of the map display data thus read, is drawn (stored) in the image memory 5.

When the processing performed in step S12 in FIG. 18 is completed, the operation proceeds to step S9, shown in FIG. 17, in which the data required to display the recommended route calculated in step S3 are also drawn over (stored) in the image memory 5. The recommended route drawing processing performed in step S9 is described in more detail later. In step S10, the data stored in the image memory 5 are read out and the recommended route and the roadmap in the vicinity are dis-

played on the display device 6.

FIG. 19 is a detailed flowchart illustrating the recommended route drawing processing performed in step S9 in FIG. 17. In step S51 in FIG. 19, the display range for the recommended route is set in correspondence to the roadmap range displayed on the display device 6. In step S52, a decision is made as to whether or not the display range for the recommended route is included within the range over which the route search has been performed using the route search data at level 4. If a negative decision is made, the operation proceeds to step S54, whereas if an affirmative decision is made in step S52 in FIG. 19, the operation proceeds to step S53 to convert the recommended route data at level 4 stored in the SRAM 7 to recommended route data at level 2. This conversion processing is to be detailed later.

Step S54 follows step S52 or step S53 in FIG. 19, and a decision is made as to whether the display scale of the roadmap is set at (1/10,000 or 1 /20,000) or (1/40,000 or 1 /80,000). If the setting is at (1/10,000 or 1 /20,000), the operation proceeds to step S55, in which the recommended route is drawn over (superimposed) in the image memory 5, based upon the recommended route data at level 2 and, the road type and link numbers of the map display data at level 1.

If, on the other hand, a decision is made in step S54 that the scale is set at (1/40,000 or 1 /80,000), the operation proceeds to step S56, in which the recommended route is drawn over in the image memory 5 based upon the recommended route data at level 2, and the road type and link numbers of the map display data at level 2.

As shown in FIGs. 13 and 14, the route search data and the recommended route data in this embodiment hold only the connection information on link connections and do not hold information in regard to road physical form. Consequently, in order to draw a recommended route superimposed upon the roadmap on the monitor, it is necessary to extract the physical form data from the roadmap data based upon the recommended route data.

FIG. 20 illustrates the procedure that is followed in order to display the recommended route on the monitor based upon the recommended route data.

FIG. 20A shows recommended route data at level 4 in which the link 1 constituting the link string 1 is present between the front end node N0 and the rear end node N1. FIG. 20B illustrates the recommended route data at level 2 and recommended route display data at level 2 for drawing the physical form data which are extracted from the roadmap display data at level 2 based upon the recommended route data at level 2, superimposed in the image memory 5. In FIG. 20B the link string 1 of the recommended route data at level 2 comprises the link 1 located between the nodes N0 and Na and the link 1 located between the nodes Na and N1. FIG. 20C illustrates the recommended route display data at level 1 for drawing the physical form data which are extracted from the roadmap display data at level 1 based upon the recommended route data at level 2, superimposed in the image memory 5.

When the operation proceeds from step S54 to step S56 in FIG. 19, i.e., when drawing the recommended route on the roadmap at level 2 based upon the recommended route data at level 2, the coordinate values of the node N0, the interpolation point Hb, the node Na, the interpolation point Hc and the node N1 constituting the link string 1, as shown in FIG. 20B, are read out by referencing the roadmap display data at level 2, with common link number 1, the start node N0 and the end node N1 of the link string 1 used as pointers. It is desirable to search the map display data within identical mesh code as the mesh code of the recommended route data in order to reduce processing time. Then, the link string comprising two links with the link number 1 in the recommended route data is drawn on the road map at level 2 which is drawn in the image memory 5.

When the operation proceeds from step S54 to step S56 in FIG. 19, i.e., when drawing the recommended route on the roadmap at level 1 based upon the recommended route data at level 2, the coordinate values of the node N0, the interpolation point Hd, the interpolation point He, the node Nb, the interpolation point Hf and the node Nc constituting the link string 1 and the coordinate values of the node Nc, the interpolation point Hg, the interpolation point Hh, the interpolation point Hi and the node N1 constituting the link string 2, as shown in FIG. 20C, are read out by referencing the roadmap display data at level 1, with common link number 1 of the two links, the start node N0 and the end node N1 of the link string 1 used as pointers. As explained before, it is desirable that mesh code at level 1 is obtained based upon mesh code of the recommended route data at level 2, then the map display data is searched within identical mesh code as the mesh code of the recommended route data in order to reduce processing time. Then, the link string comprising two links of link 1 in the recommended route data is drawn on the roadmap at level 1 drawn in the image memory 5.

It is to be noted that the processing through which the recommended route data at level 4 are converted to recommended route data at level 2 performed in step S53, is implemented by referencing the route search data at level 2 with the link number 1 assigned to one link in the recommended route data at level 4 and the start node N0 and the end node N1 of the link string 1 shown in FIG. 20A used as pointers. It is desirable to perform a search within the mesh code at level 2 which is specified by the mesh code at level 4 in order to reduce the processing time.

In contrast, in a map database apparatus in the prior art, the route search data hold the address offset information for the route display data, as shown in FIG. 24, instead of the inherent link number as in the present invention, and the physical form data are added to the recommended route data, which do not have any physical

form data, to create route display data which are superimposed upon the roadmap at the same level in image memory for drawing. For instance, in the prior art, the route search data hold address offset information 01 for the map display data at the same management level and address offset information 02 for the map display data at the lower order level in regard to a route that connects the home node and an adjacent node N1. Because of this, a problem exists in that the quantity of route search data is large. The address offset information 01 refers to the address in the roadmap display data at the same level, i.e., level 4, where the positional coordinates of the home node N0 are stored in memory and the address offset information 02 - 05 indicate addresses in the roadmap display data at the lower order level, i.e., level 2, where the positional coordinates of the home node N0 are stored in memory.

Thus, since the road physical form is detected from the roadmap display data by using the identical link number, the start node and the end node of the identical link at each level in the recommended route data as pointers in this embodiment, it is not necessary to provide address offset information for route display data in the route search data and neither is it necessary to provide road data to be used exclusively for the route display, thereby achieving a reduction in the quantity of route search data compared to the quantity of route search data in the prior art.

In addition, since, when drawing the recommended route data at level 2 superimposed upon a display map at level 1, the physical form data are directly read out from the roadmap display data at level 1 by using the inherent level numbers shared among individual levels without creating recommended route data at level 1, the processing time is reduced. It is to be noted that as explained above, the processing time can be further reduced by performing a data search only within a mesh code in the roadmap display data specified by the mesh code of the recommended route data.

Claims

1. A navigation system comprising:

   a database apparatus provided with map display data constituted of data representing road positions and physical forms provided in separate sets to correspond to different scales and route search data constituted of data representing connection states of one road connecting with another road provided in separate sets to correspond to different scales; and
   a control apparatus that, when displaying recommended route data obtained by performing a search using said route search data at a specific first scale superimposed upon a roadmap that is displayed on a monitor based upon map display data at a second scale that is larger than said first scale, reads out physical form data of said recommended route data obtained by performing said search using said route search data at said first scale based upon said map display data at said second scale and displays said physical form data superimposed upon said roadmap on the monitor.

2. A navigation system according to claim 1, wherein: links in said map display data and said route search data at said second scale that are identical to links in said map display data and said route search data at said first scale are assigned with identical link numbers as those assigned to said links in said map display data and said route search data at said first scale.

3. A navigation system according to claim 2 wherein: said control apparatus searches said map display data at said second scale based upon link numbers of links in said recommended route data at aid first scale and extracts physical form data of links sharing common link numbers.

FIG. 1

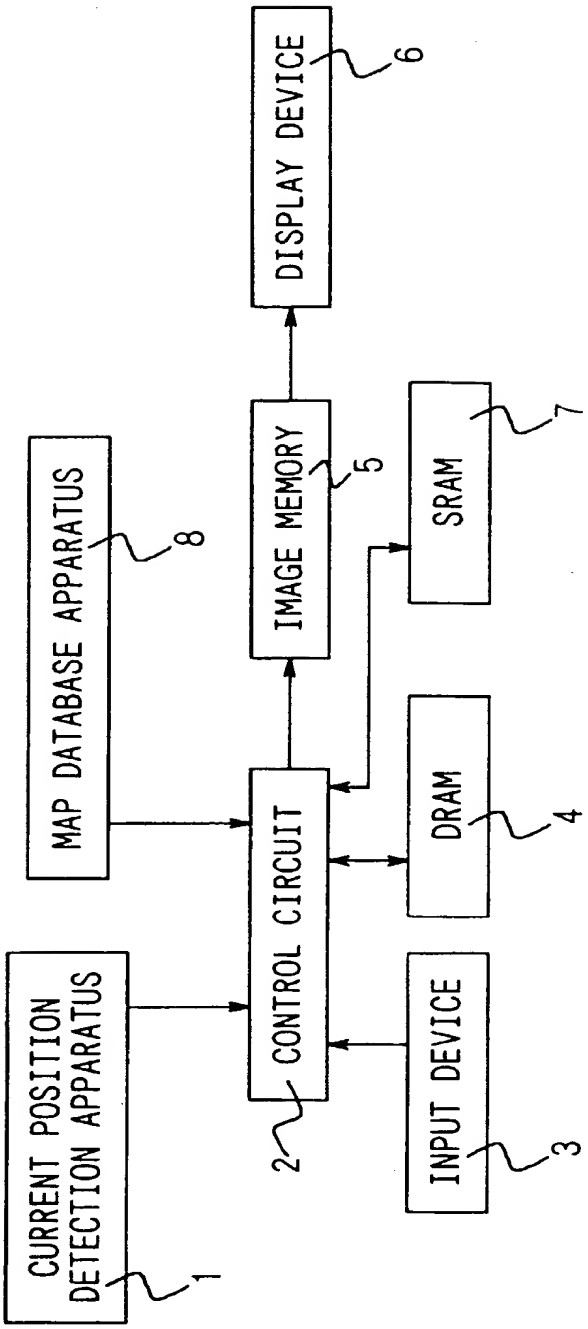

DISPLAY DEVICE
6
IMAGE MEMORY
5
SRAM
7
MAP DATABASE APPARATUS
8
CONTROL CIRCUIT
2
DRAM
4
CURRENT POSITION DETECTION APPARATUS
1
INPUT DEVICE
3

FIG. 2

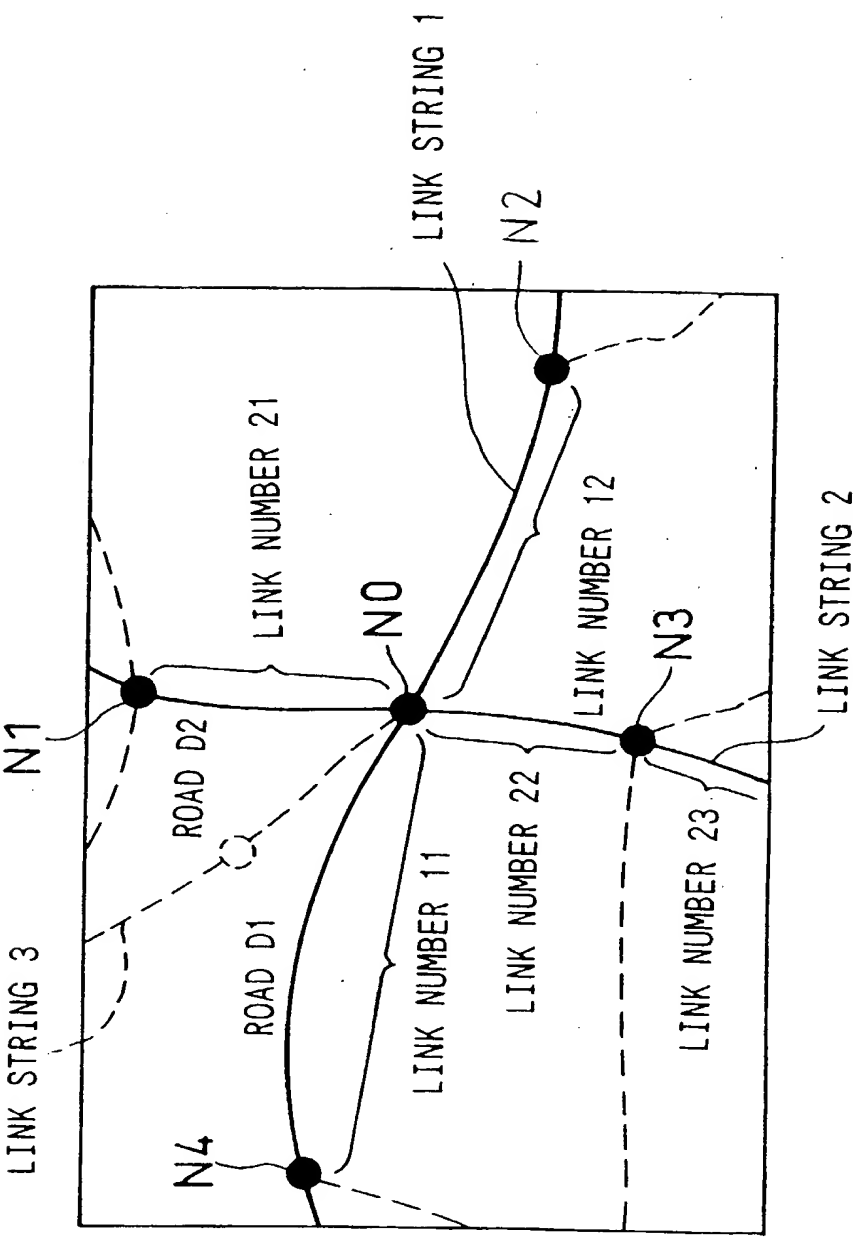

LINK STRING 1
N2
LINK NUMBER 21
LINK NUMBER 12
N0
N3
LINK STRING 2
N1
ROAD D2
LINK NUMBER 11
LINK NUMBER 22
LINK NUMBER 23
ROAD D1
LINK STRING 3
N4

FIG. 3

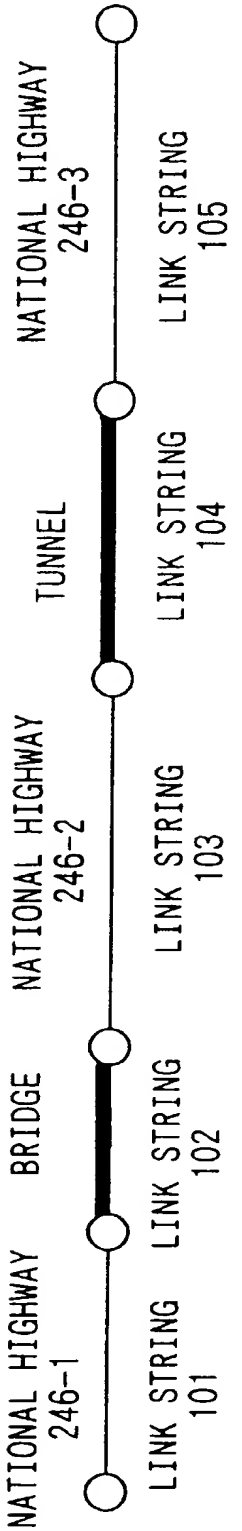

NATIONAL HIGHWAY
246-1
LINK STRING
101
BRIDGE
LINK STRING
102
NATIONAL HIGHWAY
246-2
LINK STRING
103
TUNNEL
LINK STRING
104
NATIONAL HIGHWAY
246-3
LINK STRING
105

FIG. 4

ITEM NAME		
LINK STRING 1	LINK STRING INFORMATION	LINK STRING SIZE
		NUMBER OF ELEMENT POINTS
		LINK ATTRIBUTE
		ROAD NAME OFFSET
		ROAD NUMBER
	NODE LINK INFORMATION	ATTRIBUTE 1 + X COORDINATE
		ATTRIBUTE 2 + Y COORDINATE
		(IDENTICAL NODE OFFSET)
		(GUIDE OFFSET)
		(LINK NUMBER)
		⋮
		ATTRIBUTE 1 + X COORDINATE
		ATTRIBUTE 2 + Y COORDINATE
		(IDENTICAL NODE OFFSET)
		(GUIDE OFFSET)
		(LINK NUMBER)
		ALTITUDE INFORMATION
		⋮
		ALTITUDE INFORMATION
⋮		
LINK STRING n	LINK STRING INFORMATION	
	NODE LINK INFORMATION	

FIG. 5

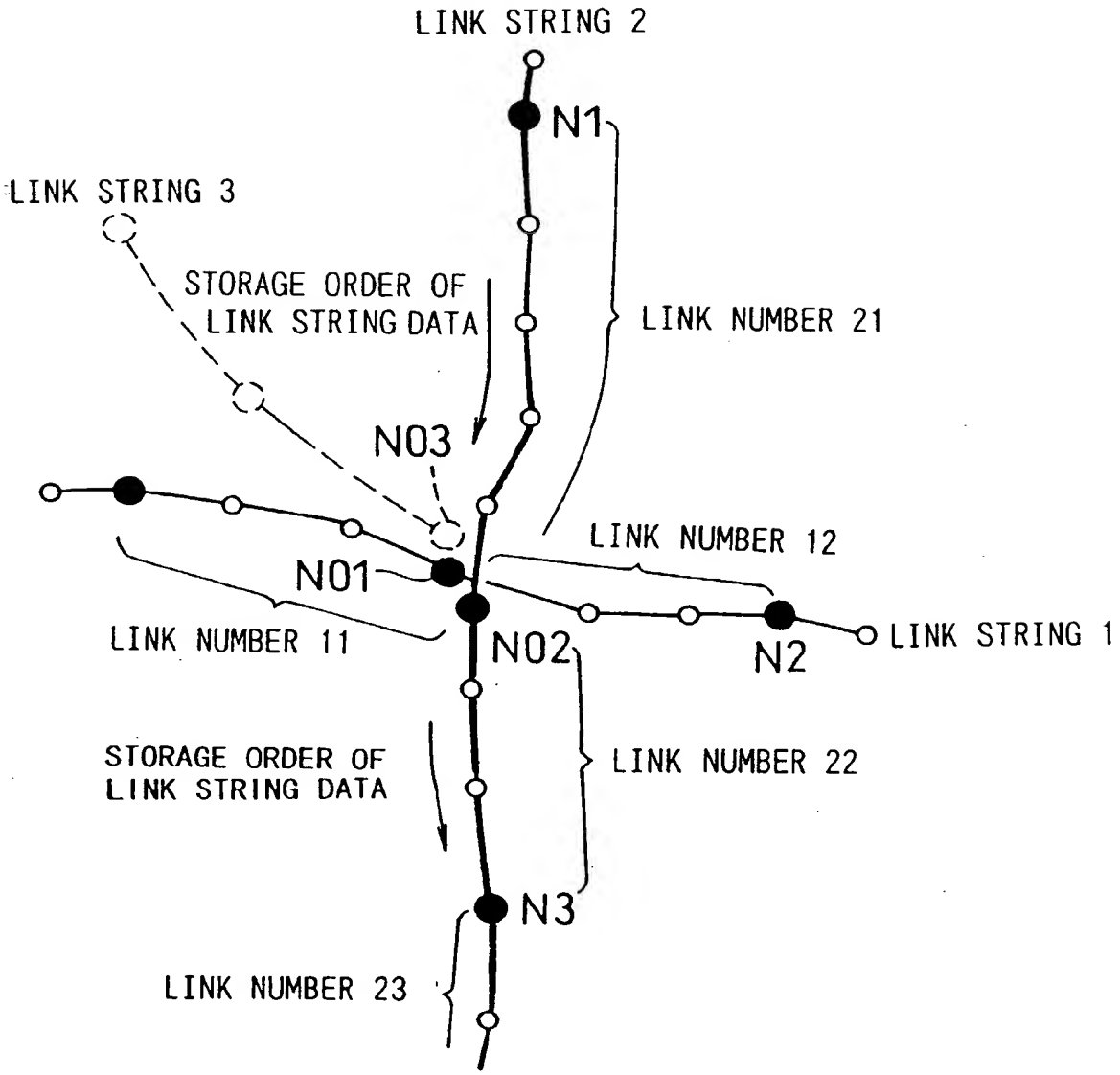

LINK STRING 2
N1
LINK STRING 3
STORAGE ORDER OF
LINK STRING DATA
LINK NUMBER 21
N03
LINK NUMBER 12
N01
LINK NUMBER 11
N02
N2
LINK STRING 1
STORAGE ORDER OF
LINK STRING DATA
LINK NUMBER 22
N3
LINK NUMBER 23

FIG. 6

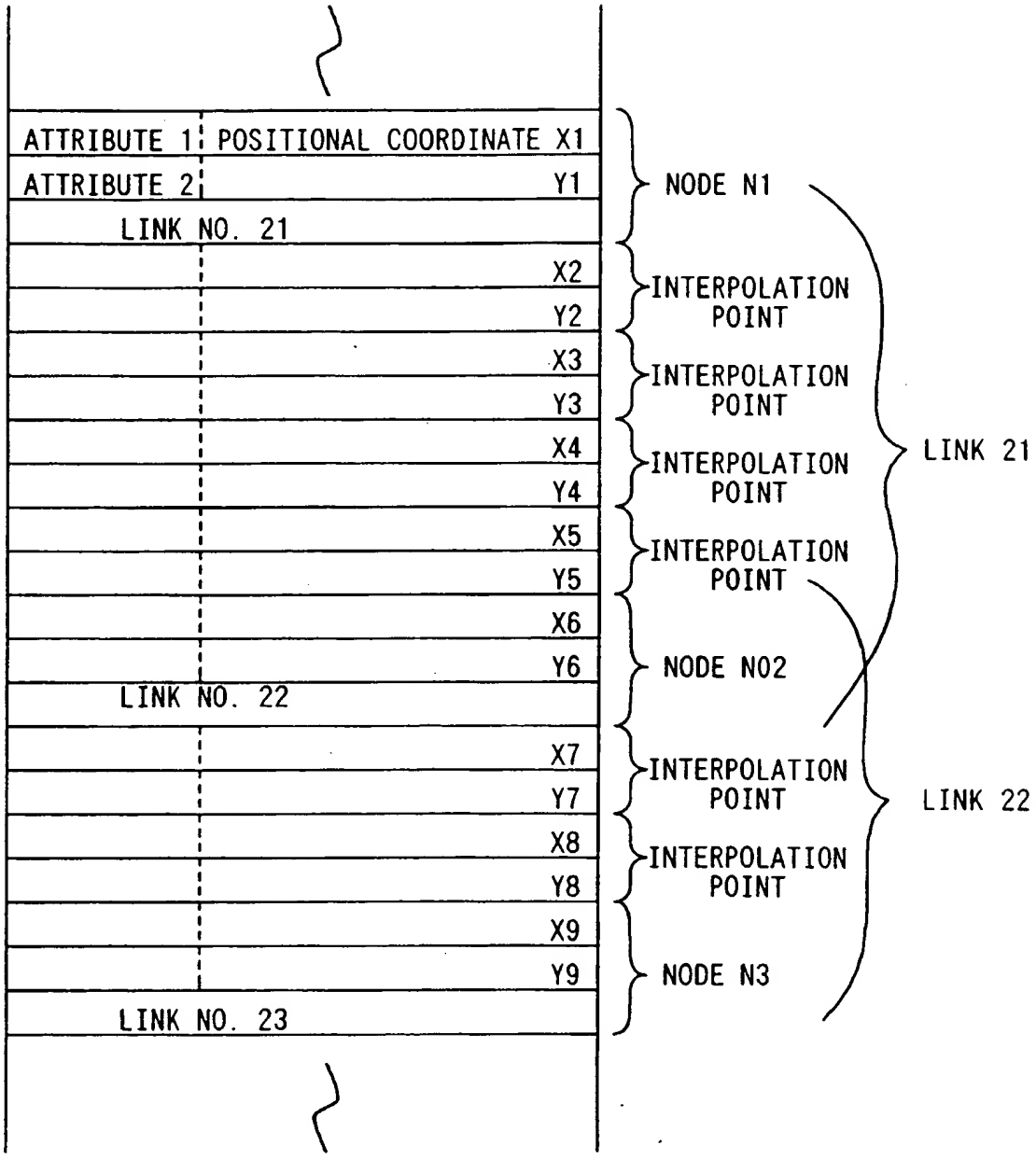

ATTRIBUTE 1
POSITIONAL COORDINATE X1
ATTRIBUTE 2
Y1
NODE N1
LINK NO. 21
X2
INTERPOLATION POINT
Y2
X3
INTERPOLATION POINT
Y3
X4
INTERPOLATION POINT
Y4
X5
INTERPOLATION POINT
Y5
X6
Y6
NODE N02
LINK NO. 22
X7
INTERPOLATION POINT
Y7
X8
INTERPOLATION POINT
Y8
X9
Y9
NODE N3
LINK NO. 23
LINK 21
LINK 22

FIG. 7

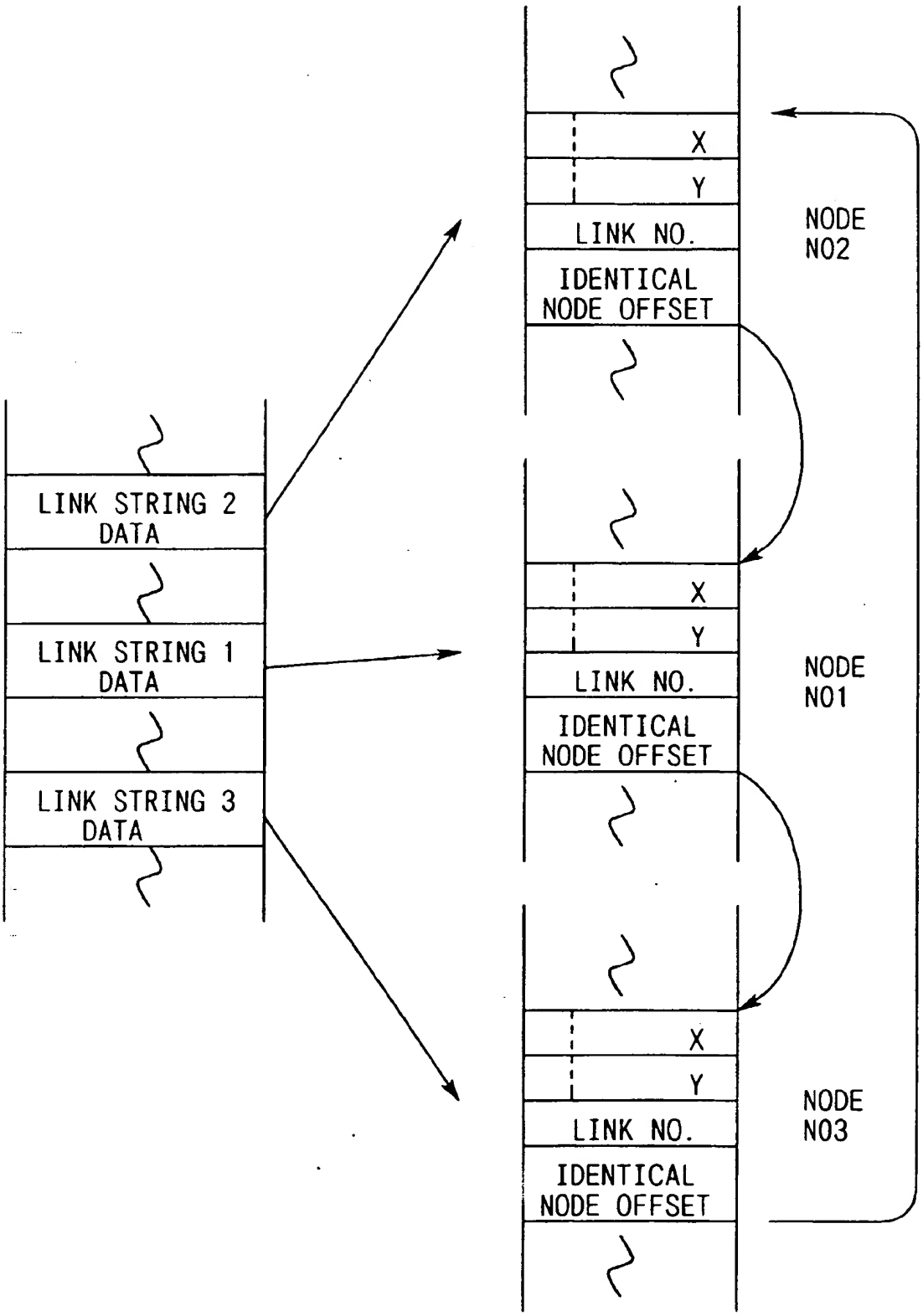

LINK STRING 2 DATA
LINK STRING 1 DATA
LINK STRING 3 DATA
X
Y
LINK NO.
IDENTICAL NODE OFFSET
NODE NO2
X
Y
LINK NO.
IDENTICAL NODE OFFSET
NODE NO1
X
Y
LINK NO.
IDENTICAL NODE OFFSET
NODE NO3

FIG. 8

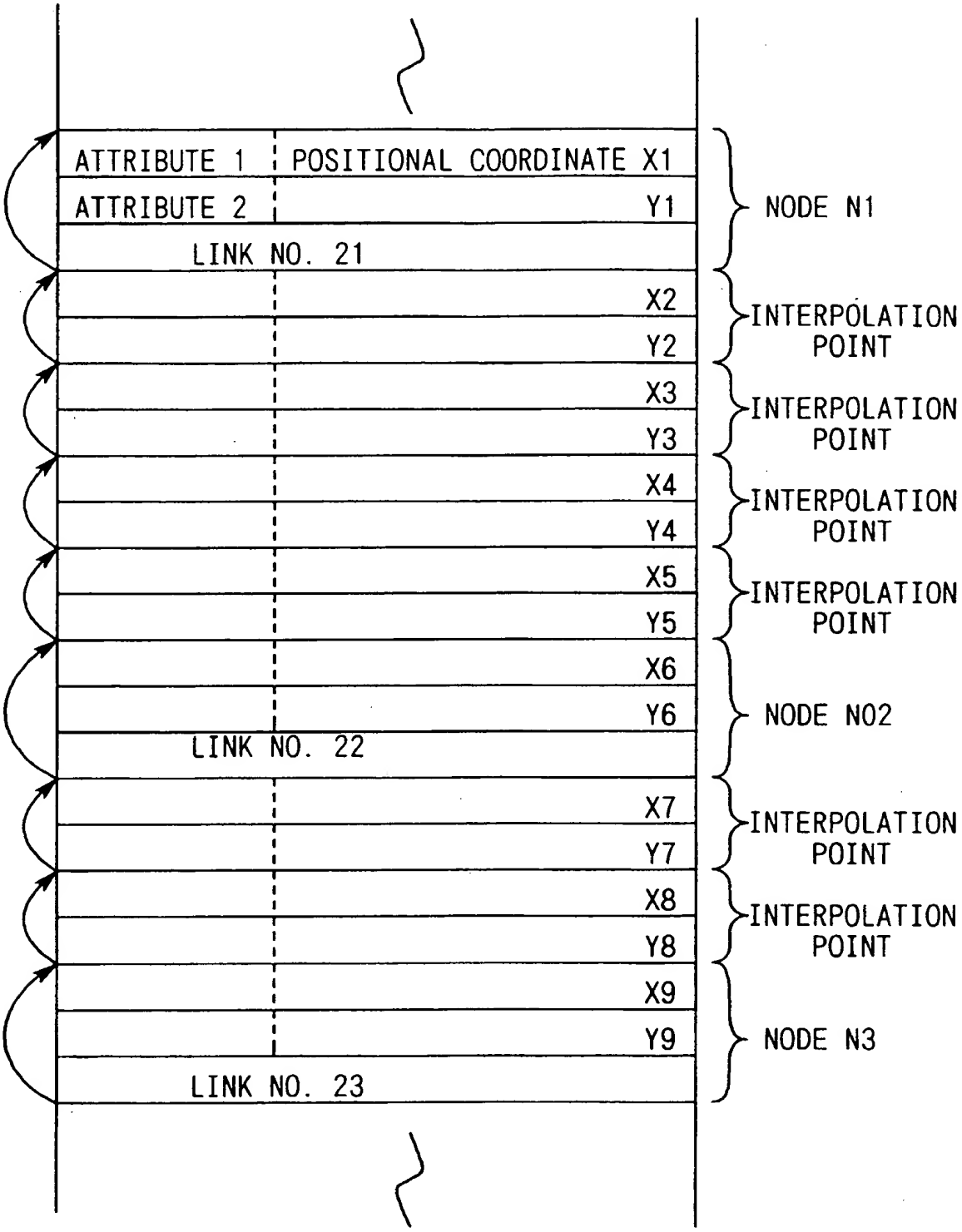
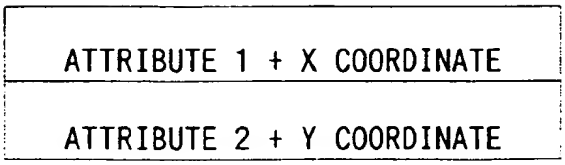
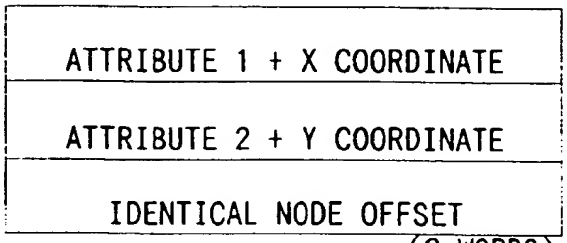

ATTRIBUTE 1
POSITIONAL COORDINATE X1
ATTRIBUTE 2
Y1
NODE N1
LINK NO. 21
X2
Y2
INTERPOLATION POINT
X3
Y3
INTERPOLATION POINT
X4
Y4
INTERPOLATION POINT
X5
Y5
INTERPOLATION POINT
X6
Y6
NODE NO2
LINK NO. 22
X7
Y7
INTERPOLATION POINT
X8
Y8
INTERPOLATION POINT
X9
Y9
NODE N3
LINK NO. 23

FIG. 9A



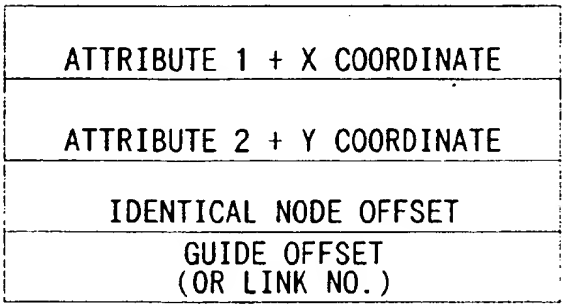
(2 WORDS)

FIG. 9B



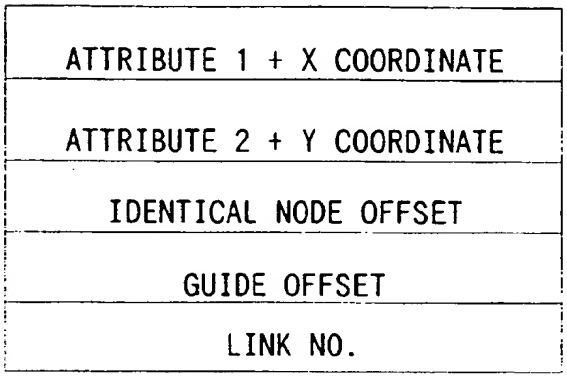
(3 WORDS)

FIG. 9C



(4 WORDS)

FIG. 9D



(5 WORDS)

FIG. 10A

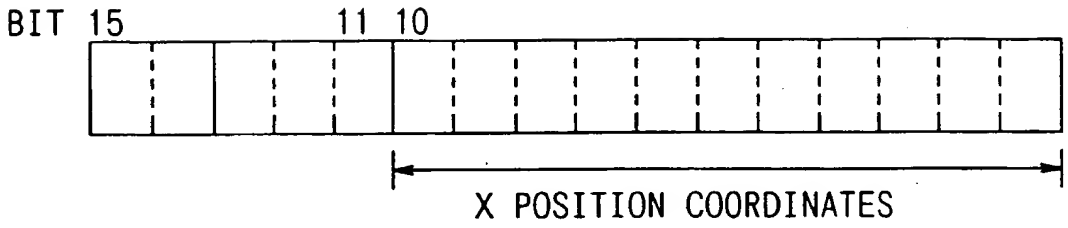


FIG. 10B

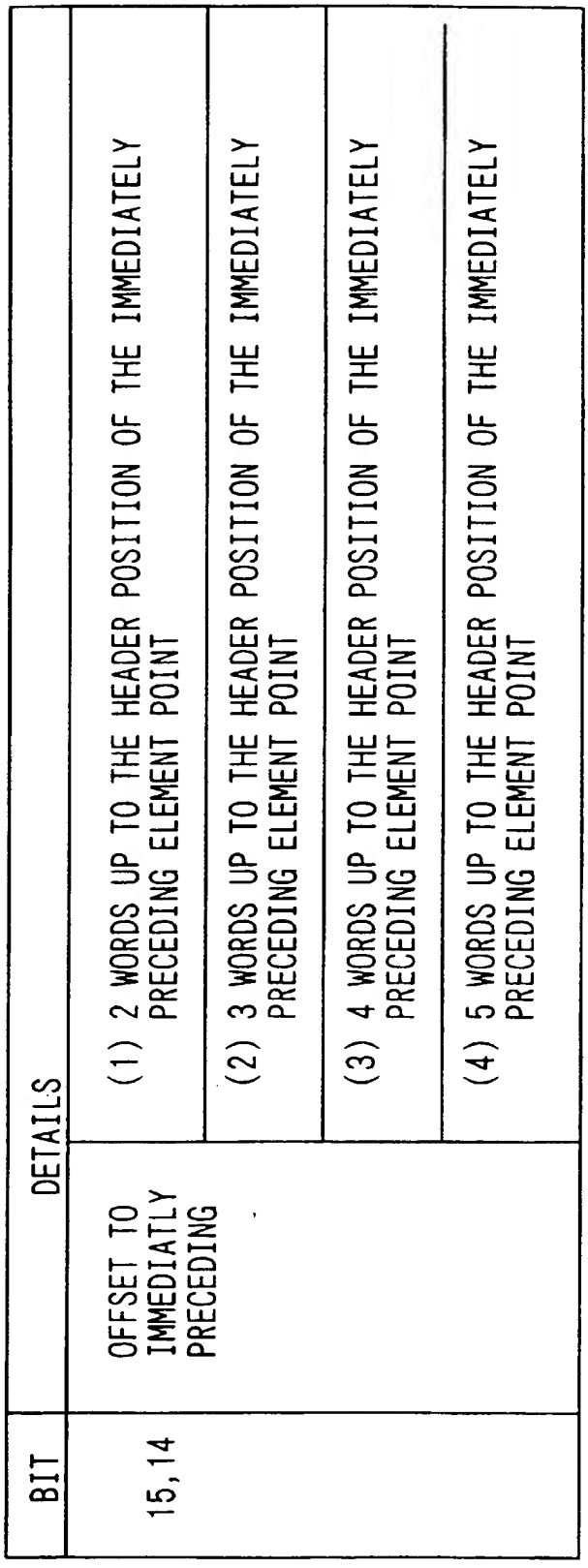

BIT
DETAILS
15,14
OFFSET TO IMMEDIATLY PRECEDING
(1) 2 WORDS UP TO THE HEADER POSITION OF THE IMMEDIATELY PRECEDING ELEMENT POINT
(2) 3 WORDS UP TO THE HEADER POSITION OF THE IMMEDIATELY PRECEDING ELEMENT POINT
(3) 4 WORDS UP TO THE HEADER POSITION OF THE IMMEDIATELY PRECEDING ELEMENT POINT
(4) 5 WORDS UP TO THE HEADER POSITION OF THE IMMEDIATELY PRECEDING ELEMENT POINT

FIG. 11A

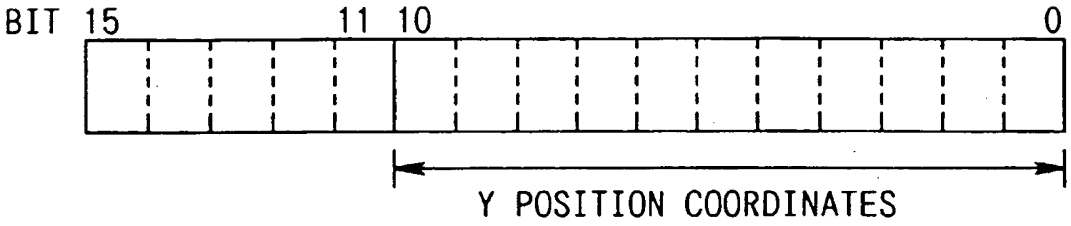


FIG. 11B

BIT	DETAILS	
15 - 11	ONE-WAY TRAFFIC	① NO ONE-WAY ROAD
		② ONE-WAY TRAFFIC IN FORWARD DIRECTION *1
		③ ONE-WAY TRAFFIC IN REVERSE DIRECTION *2
		④ NO TRAFFIC IN BOTH DIRECTIONS *3
	CLASSIFICATIONS OF WIDTHS *4	⑤ LESS THAN 5.5m OR NOT KNOWN
		⑥ 5.5 THROUGH 13m (OR ONE THROUGH 2 LANES)
		⑦ 13m OR MORE (OR THREE THROUGH 4 LANES)
		⑧ 5 THROUGH 6 LANES OR MORE

*1 1-WAY TRAFFIC IN THE FORWARD DIRECTION MEANS THAT TRAVELING IS ALLOWED ONLY IN THE DIRECTION WHICH CONFORMS TO THE ORDER IN WHICH LINK STRING DATA POINTS ARISE.

*2 1-WAY TRAFFIC IN THE REVERSE DIRECTION MEANS THAT TRAVELING IS ALLOWED ONLY IN THE DIRECTION WHICH IS REVERSE FROM THE ORDER IN WHICH LINK STRING DATA POINTS ARISE.

*3 NO TRAFFIC ALLOWED IN BOTH DIRECTIONS MEANS THAT TRAVELING IS NOT ALLOWED EITHER IN THE DIRECTION CONFORMING TO THE ORDER IN WHICH THE LINK STRING DATA POINTS ARISE OR IN THE DIRECTION THAT IS REVERSE.

*4 THE TOTAL NUMBER OF LANES FOR BOTH FORWARD AND REVERSE DIRECTIONS IS INDICATED AS THE NUMBER OF LANES. WHEN FORWARD DIRECTION LANES AND REVERSE DIRECTION LANES ARE SEPARATED, THE NUMBER OF LANES IS INDICATED SEPARATELY FOR THE FORWARD DIRECTION AND REVERSE DIRECTION.

FIG. 12

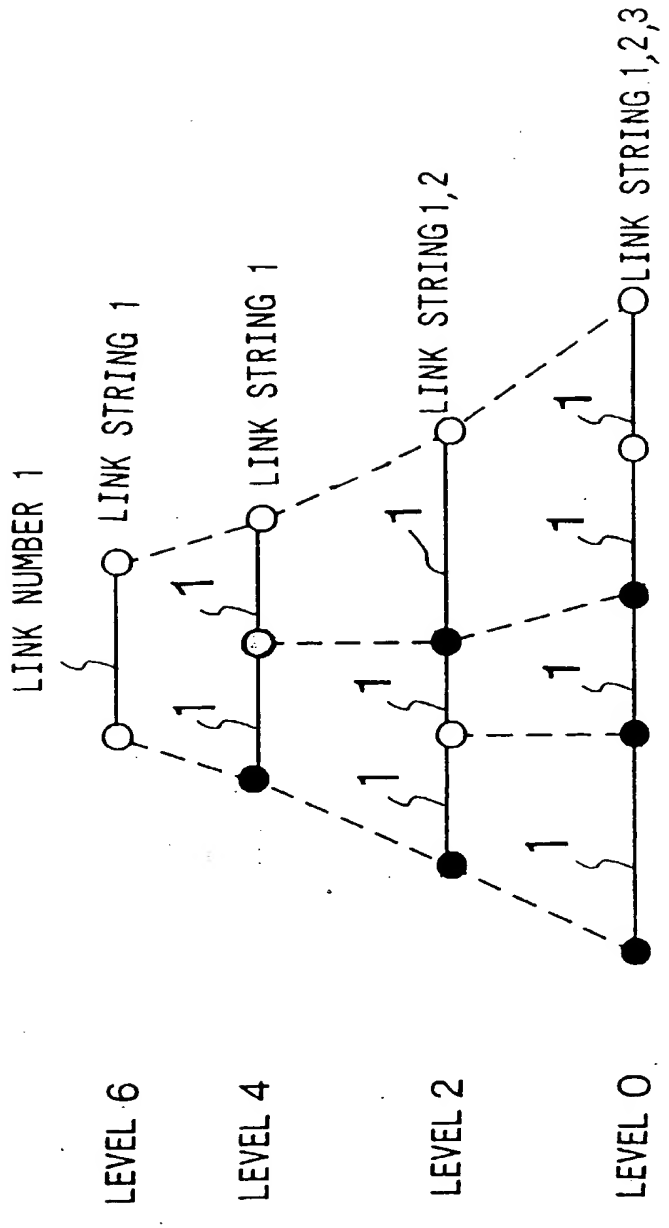

LINK NUMBER 1
LINK STRING 1
LINK STRING 1
LINK STRING 1,2
LINK STRING 1,2,3
1
1
1
1
1
1
1
1
1
LEVEL 6
LEVEL 4
LEVEL 2
LEVEL 0

FIG. 13

STRUCTURE OF ROUTE SEARCH DATA

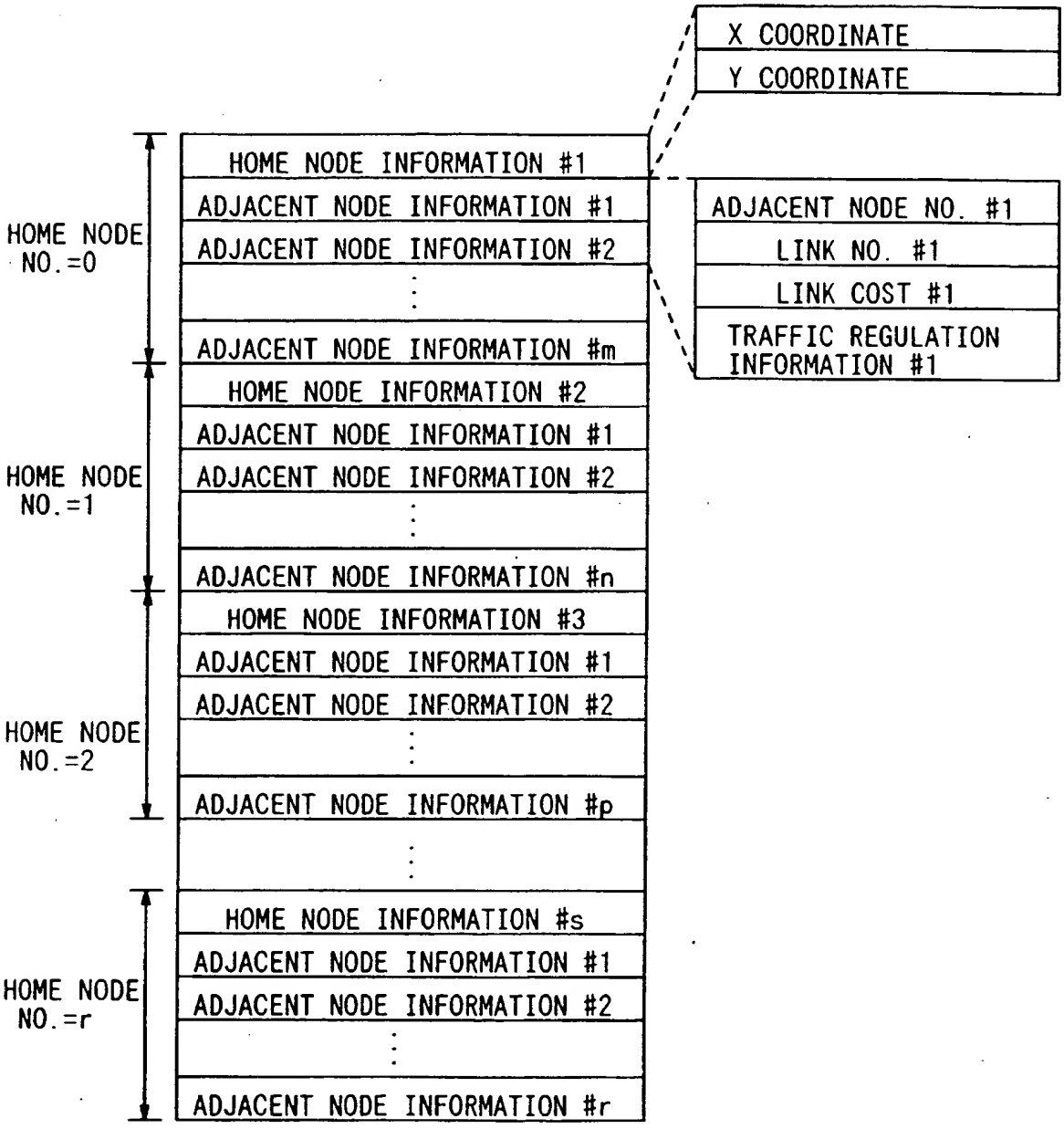
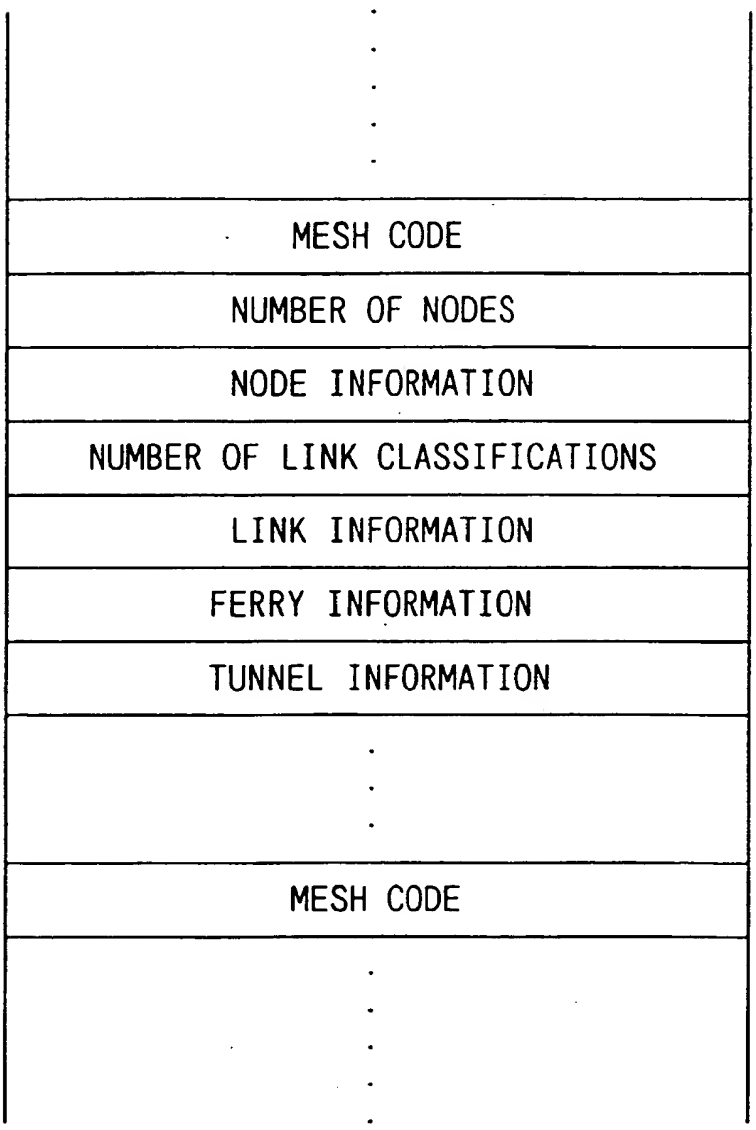


FIG. 14

STRUCTURE OF RECOMMENDED ROUTE DATA



NODE INFORMATION AND LINK INFORMATION IN RECOMMENDED ROUTE DATA

FIG. 15A

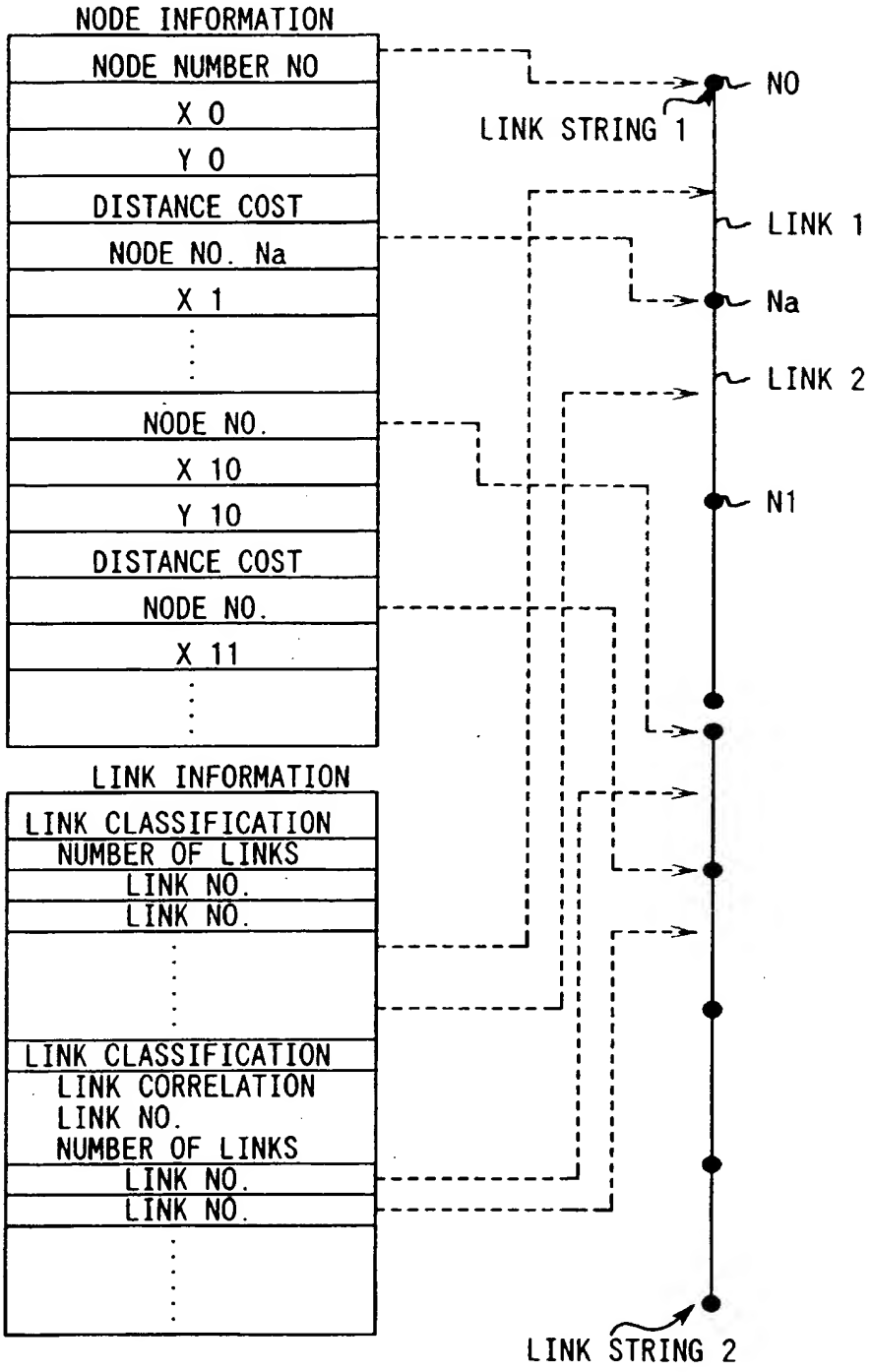


FIG. 15B

FIG. 16

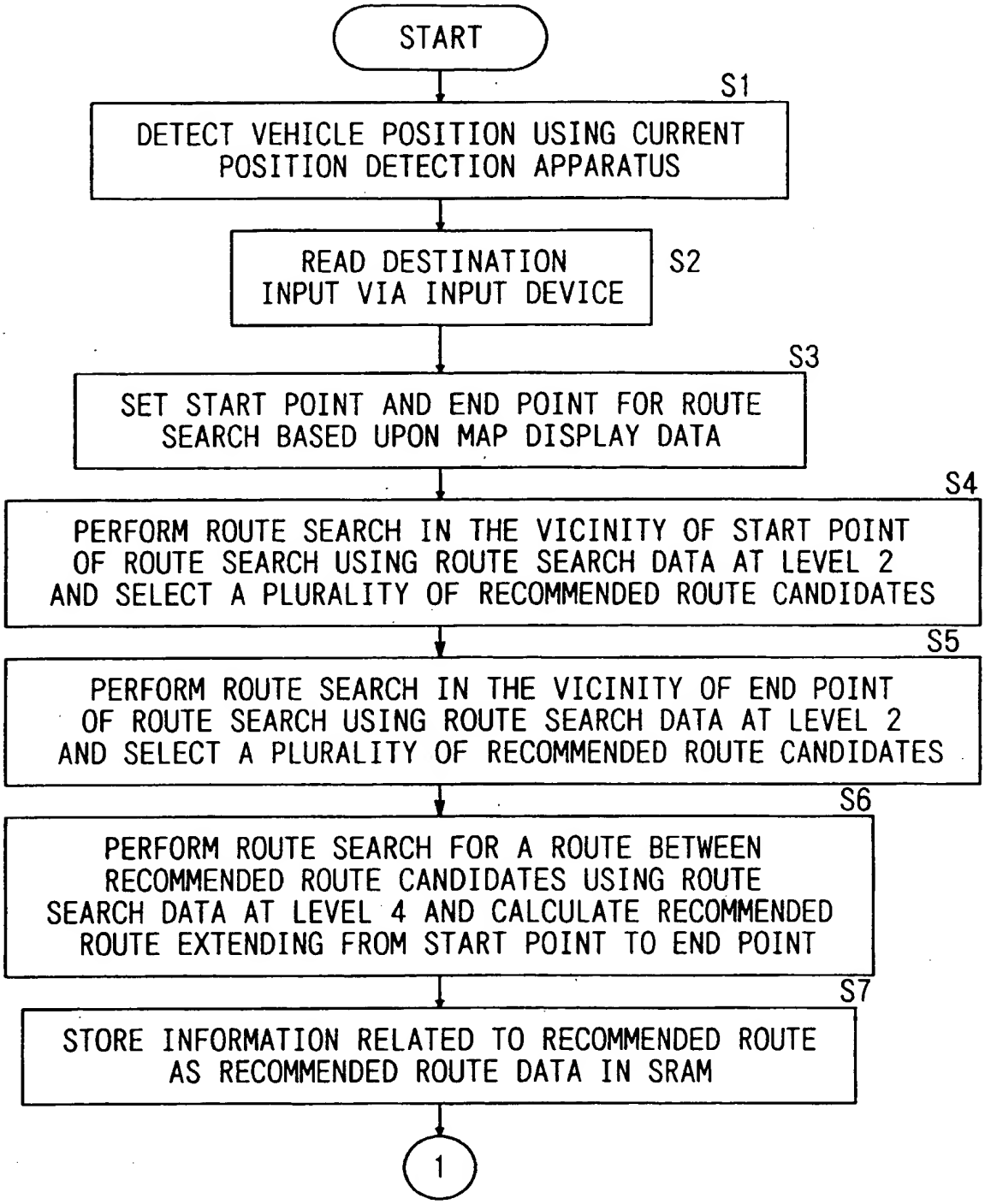

START
S1
DETECT VEHICLE POSITION USING CURRENT POSITION DETECTION APPARATUS
READ DESTINATION INPUT VIA INPUT DEVICE
S2
S3
SET START POINT AND END POINT FOR ROUTE SEARCH BASED UPON MAP DISPLAY DATA
S4
PERFORM ROUTE SEARCH IN THE VICINITY OF START POINT OF ROUTE SEARCH USING ROUTE SEARCH DATA AT LEVEL 2 AND SELECT A PLURALITY OF RECOMMENDED ROUTE CANDIDATES
S5
PERFORM ROUTE SEARCH IN THE VICINITY OF END POINT OF ROUTE SEARCH USING ROUTE SEARCH DATA AT LEVEL 2 AND SELECT A PLURALITY OF RECOMMENDED ROUTE CANDIDATES
S6
PERFORM ROUTE SEARCH FOR A ROUTE BETWEEN RECOMMENDED ROUTE CANDIDATES USING ROUTE SEARCH DATA AT LEVEL 4 AND CALCULATE RECOMMENDED ROUTE EXTENDING FROM START POINT TO END POINT
S7
STORE INFORMATION RELATED TO RECOMMENDED ROUTE AS RECOMMENDED ROUTE DATA IN SRAM
1

FIG. 17

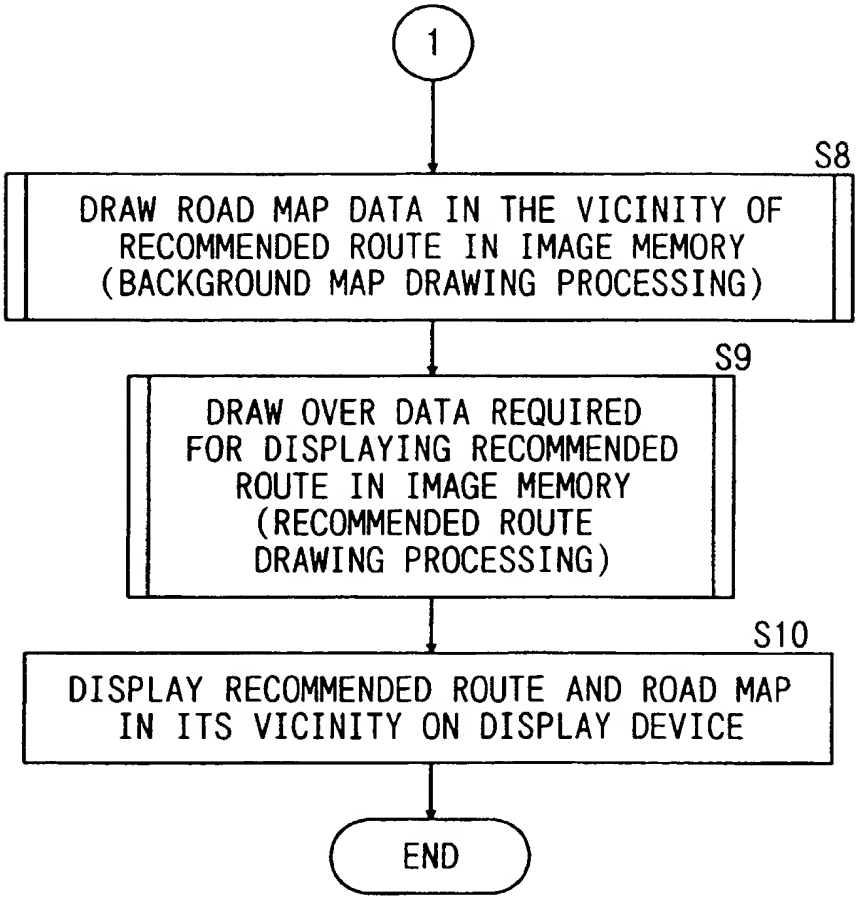

1
S8
DRAW ROAD MAP DATA IN THE VICINITY OF RECOMMENDED ROUTE IN IMAGE MEMORY (BACKGROUND MAP DRAWING PROCESSING)
S9
DRAW OVER DATA REQUIRED FOR DISPLAYING RECOMMENDED ROUTE IN IMAGE MEMORY (RECOMMENDED ROUTE DRAWING PROCESSING)
S10
DISPLAY RECOMMENDED ROUTE AND ROAD MAP IN ITS VICINITY ON DISPLAY DEVICE
END

FIG. 18

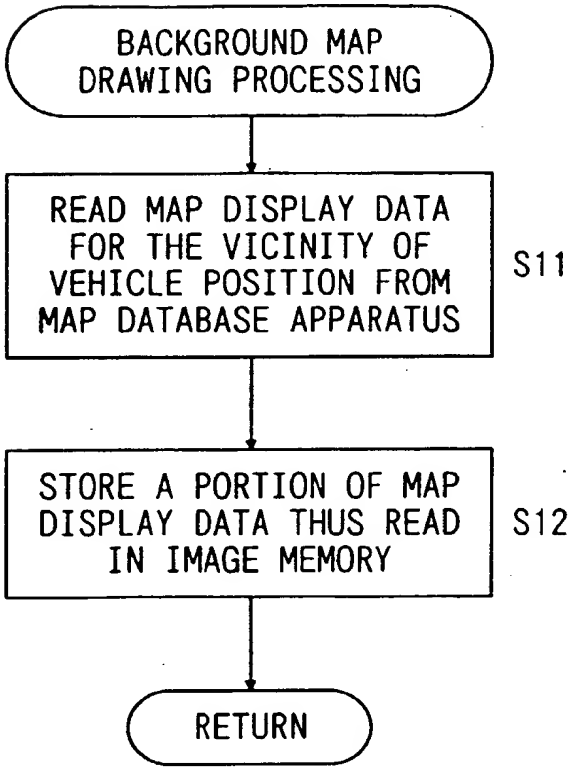

BACKGROUND MAP DRAWING PROCESSING
READ MAP DISPLAY DATA FOR THE VICINITY OF VEHICLE POSITION FROM MAP DATABASE APPARATUS
S11
STORE A PORTION OF MAP DISPLAY DATA THUS READ IN IMAGE MEMORY
S12
RETURN

FIG. 19

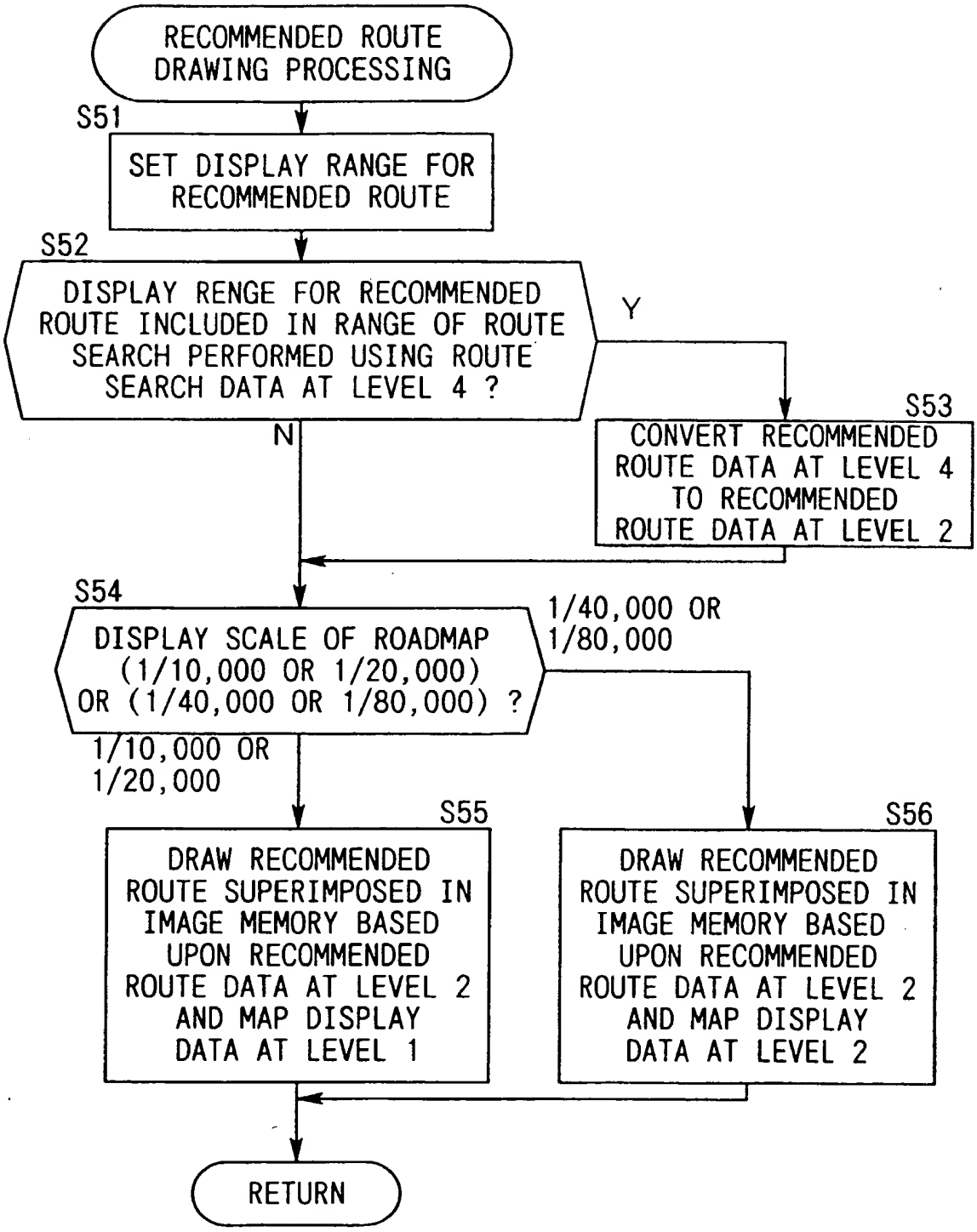

RECOMMENDED ROUTE DRAWING PROCESSING
S51
SET DISPLAY RANGE FOR RECOMMENDED ROUTE
S52
DISPLAY RENGE FOR RECOMMENDED ROUTE INCLUDED IN RANGE OF ROUTE SEARCH PERFORMED USING ROUTE SEARCH DATA AT LEVEL 4 ?
Y
N
S53
CONVERT RECOMMENDED ROUTE DATA AT LEVEL 4 TO RECOMMENDED ROUTE DATA AT LEVEL 2
S54
DISPLAY SCALE OF ROADMAP (1/10,000 OR 1/20,000) OR (1/40,000 OR 1/80,000) ?
1/40,000 OR 1/80,000
1/10,000 OR 1/20,000
S55
DRAW RECOMMENDED ROUTE SUPERIMPOSED IN IMAGE MEMORY BASED UPON RECOMMENDED ROUTE DATA AT LEVEL 2 AND MAP DISPLAY DATA AT LEVEL 1
S56
DRAW RECOMMENDED ROUTE SUPERIMPOSED IN IMAGE MEMORY BASED UPON RECOMMENDED ROUTE DATA AT LEVEL 2 AND MAP DISPLAY DATA AT LEVEL 2
RETURN

FIG. 20A

LEVEL 4

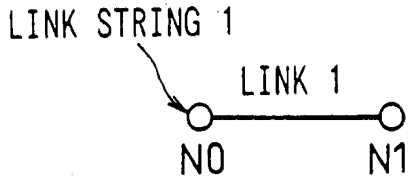
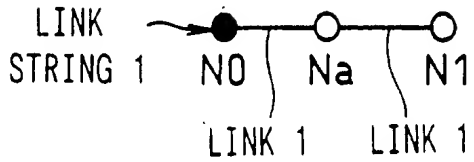


FIG. 20B

LEVEL 2



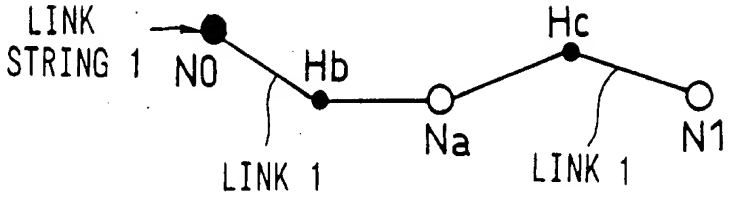
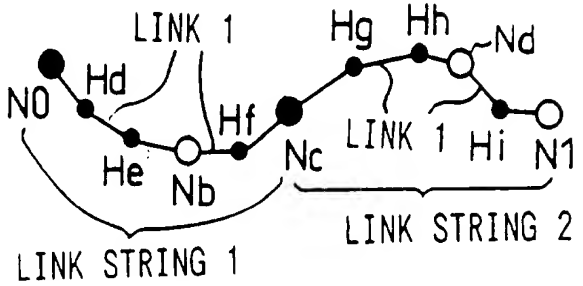


FIG. 20C

LEVEL 1



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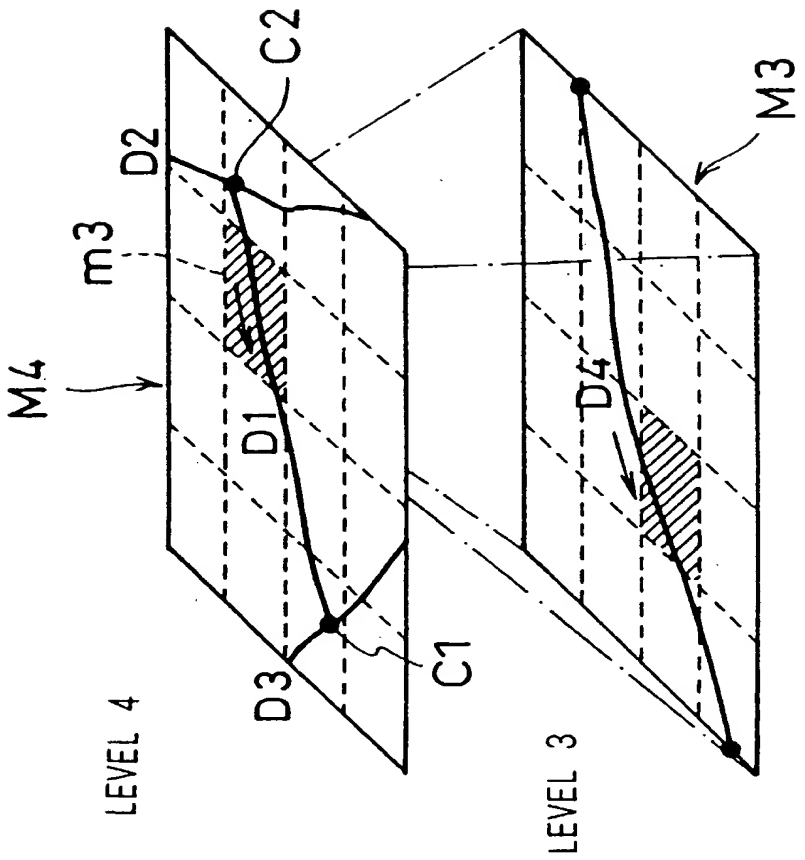


FIG. 21A

FIG. 21B

FIG. 22

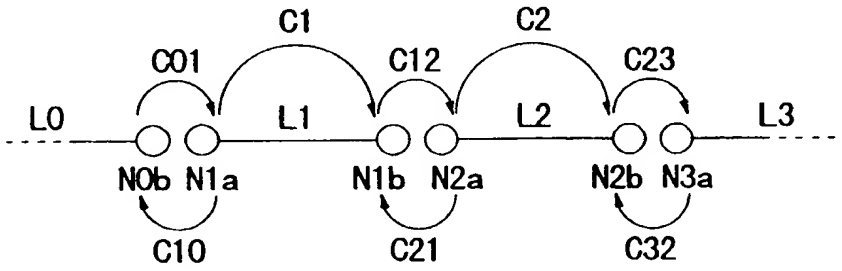

C1
C2
C01
C12
C23
L0
L1
L2
L3
N0b N1a
N1b N2a
N2b N3a
C10
C21
C32

FIG. 23

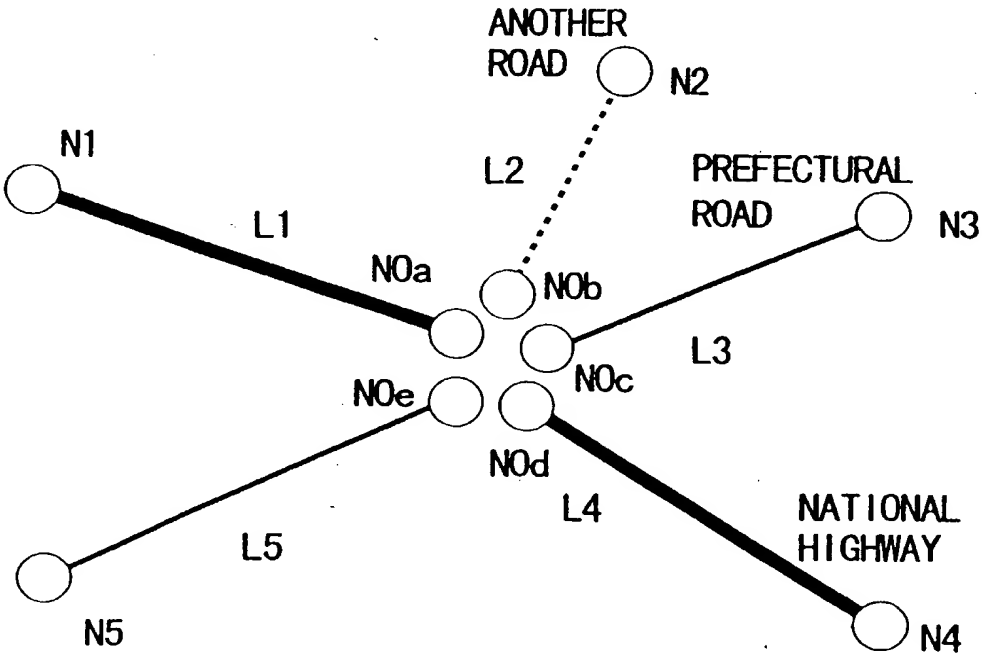
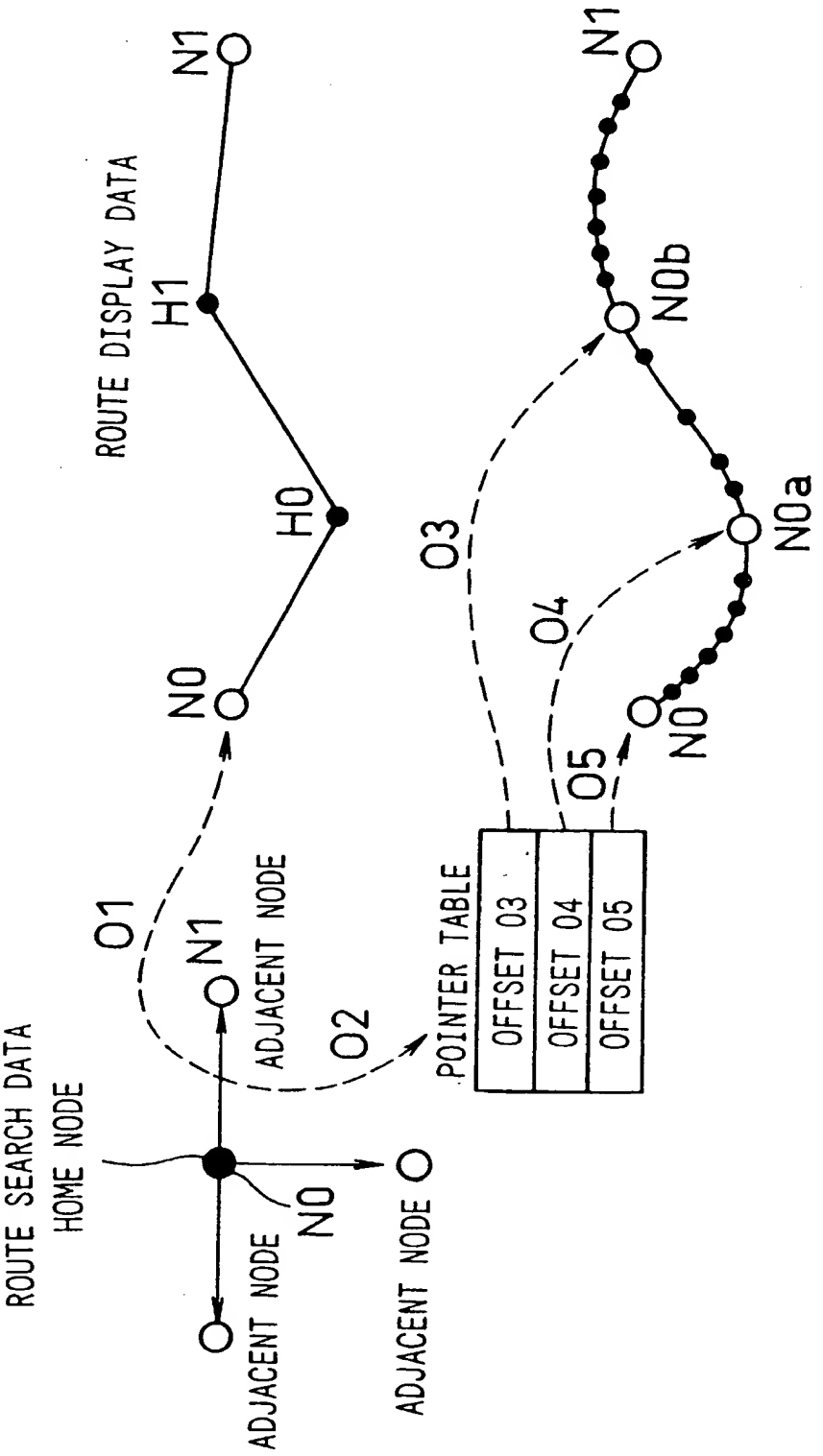

ANOTHER ROAD
N2
N1
L2
PREFECTURAL ROAD
N3
L1
N0a
N0b
L3
N0c
N0e
N0d
L4
NATIONAL HIGHWAY
L5
N5
N4

FIG. 24


ROUTE DISPLAY DATA
N1
H1
H0
N0
N1
N0b
N0a
N0
O3
O4
O5
O1
O2
N1
ADJACENT NODE
POINTER TABLE
OFFSET 03
OFFSET 04
OFFSET 05
ROUTE SEARCH DATA
HOME NODE
N0
ADJACENT NODE
ADJACENT NODE

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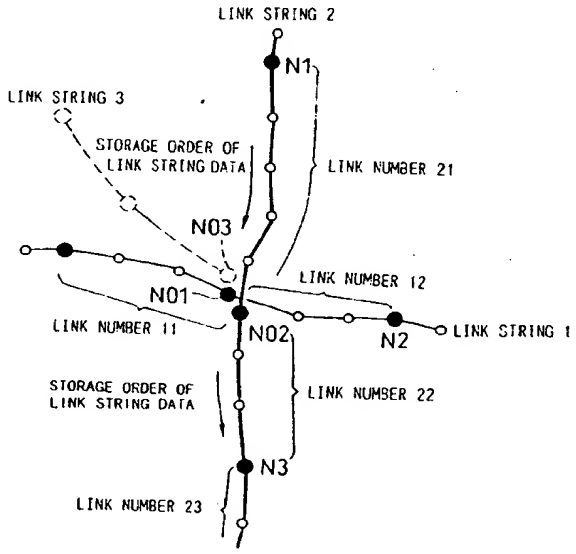
(54) Navigation system

(57) A navigation navigation system according to the present invention comprises: a database apparatus provided with map display data constituted of data representing road positions and physical forms provided in separate sets to correspond to different scales and route search data constituted of data representing connection states of one road connecting with another road provided in separate sets to correspond to different scales; and a control apparatus that, when displaying recommended route data obtained by performing a search using the route search data at a specific first scale superimposed upon a roadmap that is displayed on a monitor based upon map display data at a second scale that is larger than the first scale, reads out physical form data of the recommended route data obtained by performing the search using the route search data at the first scale based upon the map display data at the second scale and displays the physical form data superimposed upon the roadmap on the monitor.

FIG. 5



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EUROPEAN SEARCH REPORT

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EP 97 30 8378

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	EP 0 706 031 A (XANAVI INFORMATICS CORP ;HITACHI LTD (JP)) 10 April 1996 * the whole document *	1-3	G01C21/20
A	US 5 285 391 A (SMITH JR BERNARD C ET AL) 8 February 1994 * abstract *	1	
A	KAMIJO S ET AL: "DIGITAL ROAD MAP DATA BASE FOR VEHICLE NAVIGATION AND ROAD INFORMATION SYSTEMS" PROCEEDINGS OF THE VEHICLE NAVIGATION AND INFORMATION SYSTEMS CONFERENCE, (VNIS), TORONTO, SEPT. 11 - 13, 1989, no. CONF. 1, 11 September 1989, pages 319-323, XP000089898 REEKIE D;CASE E; TSAI J * page 321 *	1	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

G01C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29 September 1998	Hoekstra, F

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